A Summary of Current Program and
Preliminary Report of Progress

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HORTICULTURAL CROPS RESEARCH

of the

United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

Section B

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
December 1, 1966

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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of food available to consumers change constantly with the adoption of new practices of production, processing, and marketing. Changing constantly also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, on the nutrient and other values of foods, and on ways to conserve or enhance these values in household and institutional preparation and processing.

The kinds and amounts of foods consumed by different population groups and individuals must be determined periodically by surveys so that the nutritional adequacy of diets can be evaluated. Information on food consumption and dietary levels provides the guidelines needed for effective nutrition programs. This information also furnishes the basis for market analyses for different commodities and for development and evaluation of agricultural policies that relate to production, distribution, and consumer use of food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of improved procedures for household food preparation, care and preservation; (3) nutritional appraisal of food supplies and diets of different population groups; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service -- the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done at Beltsville and Hyattsville, Maryland; some is done under cooperative, contract, or grant arrangements with State Experiment Stations, universities, medical schools, research institutes, and industry. The total Federal scientific effort devoted to research in these areas is 72.6 man-years. It is estimated that 14.5 **scientist** man-years are concerned with studies related to horticultural products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 21.1 scientist man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to vegetables and fruits are considered briefly in this report.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Nutrient and Other Consumer Values of Horticultural Products

1. Fruits. Investigations continue on methods to determine carbohydrate fractions in foods directly and in particular to identify and determine the sugars. Total solids, total sugars, reducing sugars, sucrose, and acid content were determined in 30 fresh and 3 dried fruits. Bananas, cherries, figs, Thompson seedless grapes and Tokay grapes were highest in total solids, total sugars, and reducing sugars. Bananas were considerably higher, 8.5 percent, in sucrose than any of the other fruits. The fructose content of apples, 6.5 percent, was six times as high as the glucose. Lime juice was highest in acid, 5.6 percent, although cranberries, apricots, raspberries, rhubarb, plums, grapefruit, and sour cherries were high in acidity, ranging 2.0 to 0.9 percent. A manuscript reporting these data has been accepted for publication in the Journal of the American Dietetic Association.

Investigations of the relationship between composition and eating quality of red raspberries of two levels of ripeness have been completed. The berries were of the "Chief" variety. Level of ripeness was based on color; one group was near optimum ripeness and the other slightly past optimum. The slightly overripe berries were scored similar in flavor to the less ripe. They contained less fructose, citric acid, malic acid and alcohol insoluble solids than the less ripe. The major sugars were sucrose--about 50 percent; fructose--about 25 percent; and glucose slightly less than 25 percent. There were significant seasonal differences in both eating characteristics and composition of berries over a 3-year period.

Research was initiated on the effect of chlordane and demeton treatment of the soil upon the palatability and related compositional factors in Earlidawn and Amore strawberries. Both insecticides are effective on contact; demeton also acts systemically. The berries grown in 1965 were evaluated fresh, immediately after freezing, and after frozen storage (0° F.) for 3 months. Criteria included: panel evaluations for color, texture, and flavor; measurement of ascorbic, citric, and malic acids,

fructose, glucose, and sucrose, soluble and total solids, shear force, color, and gas chromatographic examination of head space vapors. The data are being analyzed and will be prepared for publication.

Research was initiated on the effect of the fungicides, captan and ferbam, on the quality of Sunrise and Surecrop varieties of strawberries. Criteria included: palatability; physical measurements of quality; and content of reduced and oxidized ascorbic acid, soluble solids, pectins, alcohol insoluble solids, sugars, organic acids and total solids. Strawberries are being evaluated within a day after harvest.

Research on palatability of blueberries grown in herbicide-treated soil in New Jersey was continued in cooperation with the Crops Research Division. For the 1965 crop, blueberries grown on soil treated with diuron and simazine at different rates and times of application were analyzed for total solids, sucrose, glucose, and total and reducing sugars. Correlations with palatability evaluations and pesticide treatment will be investigated.

The effect of herbicide treatment on quality and nutrient content were determined on Red Rome apples from the 1965 crop grown in New Jersey. Diuron, simazine, CIPC (Isopropyl N(chlorophenyl)carbamate) and amitrole were compared with a plastic mulch treatment, a weedy control, and a clean control. Components being determined include total solids, total dissolved solids, sucrose, glucose, fructose, total and reducing sugars, titratable acids and the mineral elements copper, iron, chromium, zinc, and manganese. Yields of apple flesh and apple peel were calculated. Quality was evaluated by a trained panel and by Kramer shear measurements. The work is in progress.

2. Vegetables. The effect of degree of ripeness upon palatability and acid and sugar constituents was studied in Hearts of Gold and Hale Best cantaloupes grown in Maryland. Cantaloupes ranged from the hard, green stage to ripe. Flavor intensity was not related to softness or shear value in fully ripe, but they were related in the less ripe cantaloupes. Both flavor intensity and sweetness were greater in the riper cantaloupes, and these were associated with an increase in content of sucrose (about 15 percent) and malic acid (about 20 percent) and a decrease in glucose (about 25 percent).

Research continued on the relation of cell wall constituents to eating quality and dealt mainly with pectin and lipid components of fresh and frozen cantaloupe. PMR-450 and PMR-45 varieties of cantaloupes were obtained from the U. S. Horticultural Field Station at LaJolla, California. The criteria used included microscopic examination of stained sections for qualitative differences in cell structure and constituents; taste panel evaluations of texture; and Lee-Kramer Shear press measurements. Effects

of freezing and storage at 0° F. for 4 and 8 months on firmness, tenderness, and sweetness were investigated for the above varieties and for Hale Best variety from two locations in Maryland. The data are being analyzed and a manuscript will be prepared. Manuscripts also are in preparation on some methodological aspects of the histological work.

An investigation was made of relationships between composition and eating quality of six varieties of fresh tomatoes varying in color from yellow to red and believed to vary widely in acid content and keeping quality. The two varieties of yellow tomatoes studied, generally thought to be low in acid, were higher in acid content than were the four varieties of red tomatoes investigated. Considerable amounts of galacturonic acid, not previously reported in fresh tomatoes, were found in all varieties investigated. The varieties which had lower panel scores for intensity of natural flavor also had lower amounts of citric acid, fructose, titratable acids, and soluble solids, and had lower ratios of soluble solids to titratable acids. Panel flavor scores were significantly correlated with soluble solids, pH, and soluble solids-titratable acids ratios. This work was done in cooperation with the Crops Research Division. A manuscript giving the findings has been prepared for publication.

Under contract with the National Canners Association in Washington, D. C. and Berkeley, California, research on the effect of preparation and cooking on the pesticide residues of selected vegetables is in progress. Pesticide treatment and residues were within recommended tolerances. Findings show that approximately two-thirds of the DDT residues on field-treated tomatoes were removed by cold water washing and that nearly all the remaining residue was removed by commercial canning and juicing operations and by home preparative procedures. Cold water washing removed about one-half of the Sevin residues from field-treated tomatoes; commercial peeling and canning operations and home preparative procedures removed nearly all the remaining residue. However, no loss of DDT or sevin occurred during storage of the raw, unwashed fruit at 55° F. for 2 weeks.

Soaking and cooking procedures for dry beans were investigated to select procedures for pinto, navy, great northern, and kidney beans that will produce tender, palatable products under conditions of large quantity food service. The addition of baking soda in small amounts (0.07 percent) to the soaking liquid shortened the cooking time by about one-half without impairing eating quality. Using the soaking water instead of fresh tap water for cooking the beans helped retain the flavor. The nutritional implications of this procedure will be examined.

Green and yellow dry split peas were found to be interchangeable in formulas for institutional use. Dry split peas should be cooked in lots no larger than 25 serving portions to prevent breaking up of the peas in the bottom of the saucepot. A variety of uses for split peas in quantity food service was developed.

Reconstitution procedures were developed for dehydrated sweetpotato flakes produced by a new process involving enzyme treatment to permit use of shorter curing times for the sweetpotatoes before processing. One part of flakes to two parts of water by weight produced a more palatable product than did the use of larger proportions of water. This is a similar proportion to that recommended for flakes made by previous methods and used in the National School Lunch Food Buying Guide and quantity recipes. A manuscript presenting these data has been prepared.

3. Potato products. The substitution of commercially prepared for home-prepared food presents problems to the dietitian and nutritionist in the calculation of nutritive values of diets. Nine potato products in one or more market forms were analyzed both as purchased and ready-to-serve, and except for potato chips, the comparable home-prepared product also was analyzed. Products from dehydrated mixes (au gratin, hash-browned, scalloped, soup) tended to be higher in carbohydrate and ash (15 and 17 percent higher), and lower in protein (27 percent lower) than the home-prepared counterparts. Frozen au gratin and potato soup were more nearly like home-prepared forms than the other commercial forms. For potatoes cooked in fat, variation in different samples of individual brands (french fries, 7 to 16 percent fat; puffs, 9 to 21 percent fat; chips, 30 to 37 percent fat) as prepared for serving or as eaten, was greater than among the brands or market forms.

Research was initiated on changes in the palatability, cooking quality, and related biochemical properties during home storage of potatoes grown in soil treated with PCNB (pentachloronitrobenzene) for protection against black scurf and scab. Potatoes are being evaluated after harvest, after 1 month's storage at 70° F., and after 2 and 5 month's storage at 55° F. Criteria include free phenols, polyphenol oxidase, tyrosine, starch, reducing and non-reducing sugars, citric and malic acids, specific gravity, color, texture, and flavor. Bud and stem ends of potatoes are being evaluated separately. Potatoes grown in Virginia, Minnesota, and Washington were studied in 1965 and work will continue on potatoes from the 1966 season.

An earlier study published during the year indicated that potatoes grown in PCNB-treated soil had higher polyphenol oxidase and cytochrome oxidase activities and lower total phenolic content than potatoes grown in untreated soil. This indicates that PCNB brings about changes in the metabolism of tubers grown in treated soil. In this study Red Warba potatoes were grown in untreated soil and in soil treated with 25 pounds PCNB per acre and Cobbler potatoes grown in untreated soil and in soil treated with 50 pounds PCNB per acre. The Red Warba potatoes were grown in North Dakota in 1960, and the Cobbler potatoes in New Jersey in 1961.

B. Tables of Food Composition

1. B-vitamins and trace elements in foods. Summarization of data and derivation of representative values are nearing completion for a publication on the content of pantothenic acid, vitamin B_6 and vitamin B_{12} in foods. The values will be given in terms of milligrams of the nutrient per 100 grams of edible portion and per 1 pound as purchased for each food item.

Also nearing completion is a preliminary table summarizing the data for 22 trace elements in foods arranged in 15 food groups. Data representing over 6,500 food samples analyzed for 1 to 22 trace elements have been reviewed, recorded on cards for punching and sorted by specific food. This table is particularly useful for indicating foods and food groups for which data are very limited or are conflicting.

2. Vitamin E. A review of the vitamin E content of more than 5,000 food and feed items used for human and/or animal consumption was completed and published by the University of Wyoming at Laramie. This review was proposed and partially supported by the Human Nutrition Research Division. A total of 455 references were reviewed and fewer than 40 contained information on individual forms of tocopherols. The review was instigated by the increased recognition given to the importance of the tocopherols in metabolism of polyunsaturated fats and the extent of their use as naturally occurring antioxidants.

C. Nutritional Requirements

Laboratory work has been completed on a study to measure the metabolic response of adolescent girls, 16-19 years of age, to a controlled ovo-lacto-vegetarian type diet. The study was conducted under contract with Andrews University at Berrien Springs, Michigan. All 16 girls studied were maintained in positive nitrogen balance while they ate the controlled diet containing a moderate amount of protein (about 64 grams per day). Of particular interest was the positive balance maintained by one subject when she was in a febrile condition. This observation suggests that it is possible to maintain previously healthy individuals on moderate allowances of good quality protein during short febrile periods. Negative calcium balances in a number of the subjects showed that calcium intakes of approximately 1 gram per day were not enough to ensure meeting the needs of these older adolescent girls. The extent of the negative balances indicated that intakes of approximately 1.3 grams per day, as recommended by the National Research Council, probably would have maintained all the subjects in positive balance. The very low positive and slightly negative magnesium balances achieved on intakes of approximately 320 mg per day suggest that a magnesium allowance of at least 300 mg per day might be a realistic recommendation for this age group.

D. Nutritional Evaluation of Sweetpotatoes as Protein Source

One way to extend scarce protein supplies is through improving physiological utilization. The relative economy of improving human nutrition with minimal increases in protein content of diets has been little explored. Under a PL 480 grant at Taiwan, Formosa, partial substitution of polished rice with sweetpotatoes has been studied in man and compared to supplementation with additional protein and with minerals and vitamins when fed to weanling rats.

Gain in weight of rats during 8 weeks was increased about 50 percent by sweetpotatoes replacing 10 percent of the rice calories, 100 percent by supplementation with standard mineral and vitamin mixtures, 200 percent by supplementation with soybean meal and fish flour (6 percent additional protein) and 250 percent by the protein and mineral-vitamin supplementation combined. Sweetpotatoes or the minerals-vitamins supplement each stimulated food intake. At first, feed efficiency (weight gain per unit of feed intake) was markedly higher on the protein supplement than on the sweetpotatoes or the minerals-vitamins supplement, but by the end of 8 weeks it was much lower and was similar on all diets except the basal unsupplemented rice.

Protein efficiency ratios (PER) (weight gain per gm of protein consumed) for 4 weeks and also for 8 weeks were higher with sweetpotato supplementation than without, regardless of whether the diet contained supplements of minerals and vitamins or of protein or of both. Protein efficiency ratios for the first 2 or 4 weeks exaggerated the benefits from protein supplementation alone, compared to 8 weeks PER levels from sweetpotatoes or from the minerals-vitamins supplement each without additional protein. The standard minerals-vitamins supplement did more to sustain steady high PER over the 8 weeks tested than did either the sweetpotatoes or the protein supplement to the basal diet which contained 93 percent rice by weight. These results on rat growth and others from the human metabolic studies indicate that protein supplements to human diets may be more or less wasted unless deficiencies in non-protein nutrients of the diets are also corrected.

E. Food Consumption and Diet Appraisal

1. 1965 nationwide survey. Collection of data from the more than 15,000 households and 13,000 individual family members cooperating in the nationwide survey of food consumption in the United States is now complete. Tabulation of the data from households and preparation for tabulation of the data on individuals are in progress.

Preliminary review of the household data shows that family expenditures for food averaged $33 a week in the spring of 1965. Of this, $27 went for food bought and used at home, $6 for meals and snacks eaten away from home. Home-produced and other foods for which no direct money outlay was made were valued at $2. The money value of the food used averaged $10.65 per person.

The total money value of food per family was 17 percent greater in the spring of 1965 than in 1955 when a similar survey was made. Most of the increase can be attributed to higher food prices but there was also a substantial increase in spending by farm families for food bought and eaten away from home. Their expenditures for eating out nearly doubled in the 10-year period and took 11 percent of total food money in 1965 compared to 7 percent in 1955. A report of the preliminary findings of the money value of food of households is being prepared.

Later, information will be available on the types and quantities of foods used by families in the spring of 1965. There will be information on approximately 250 foods--the percentages of families using the foods, average amounts, and the money value of the food used. Where pertinent, data will be shown separately for purchased, home-produced, and Federally donated food. Publications will be prepared on dietary levels provided by the foods used. Similar information will be published also for the 4 seasons. For individual family members, data will be reported for about 20 different sex-age groups, for the U.S. total and probably for 2 regions.

2. Diets and nutriture of preschool children. A study was initiated to determine the nutritional situation of children, 2 and 3 years of age, in low-income families in Hawaii. Children from low-income families will be compared with those from higher income families with similar ethnic backgrounds. Biochemical, clinical, and psychomotor tests will be used to assess nutritional state. Correlations will be sought with social and economic characteristics of the child's family. The study will be done under a Cooperative Agreement by the University of Hawaii.

3. Household practices in homefreezer management. Preliminary review of the data collected during July 1964-April 1965 from 240 urban and 242 farm families in and near Fort Wayne, Indiana, showed that of the reasons given for urban families for acquiring a homefreezer about 40 percent were related to convenience--e.g., to have food on hand and to save shopping time. About 40 percent were related to economy--e.g., to buy meat by the side or quarter and to freeze local and home grown fruits and vegetables in season. The remaining 20 percent were miscellaneous reasons. The reasons given by farm families were similar to those by urban families.

Fewer urban than rural households, 60 percent vs. 70 percent, kept the temperature of the storage areas in their freezers at the recommended temperature of 0° F. or below. Twenty-five percent of the freezers in urban households and about 35 percent of those in farm households were equipped with a thermometer.

Reports of these and other findings from the study are now being prepared as articles for publication in Family Economics Review. Preparation of a more comprehensive report will follow.

4. Nutritive value of national food supply. Estimates of food energy (calories) and selected nutrients provided by the per capita food supply are calculated each year from data on apparent civilian consumption, retail basis, developed by the Economic Research Service. The estimates indicate that for the past 10 years the level of food energy has remained around 3,150 calories per capita per day--about 10 percent lower than in 1909-1913. This lower calorie level is the net result of about a 25 percent decrease in carbohydrate available for consumption, a 15 percent increase in available fat and a slight decrease in available protein, between 1909-1913 and 1965. This shift in the composition of the food supply caused the percentage of total calories furnished by carbohydrate to drop from 56 to 47 and the percentage of total calories furnished by fat to rise from 32 to 41. The percentage of total calories furnished by protein remained at about 12.

5. Nutritive content of school lunches. A nationwide study of the nutritive content of type A school lunches as served to sixth graders was initiated in cooperation with the School Lunch Division, Consumer and Marketing Service. Plans call for the collection and analysis of 20-lunch composites from 300 schools located in 19 states in five geographic regions. The objective is to provide data needed in evaluating the type A pattern. Because the pattern specifies the minimum amounts of foods required but does not specify maximum amounts that are allowed, the fat content of the lunches is of special concern.

F. Support for Food and Nutrition Programs

Developments in nutrition research continue to be studied and interpreted for application to problems in food selection and food use.

In anticipation of the expansion of child feeding programs, meal patterns for breakfasts and dinners suitable for children of all ages, were developed at the request of the School Lunch Division, Consumer and Marketing Service. These meal patterns will serve as guidelines for planning meals to meet the needs of children for food energy and the major nutrients. The patterns may be used independently or in conjunction with the type A lunch pattern.

To help promote better nutrition among low-income families, NCU food specialists and nutrition specialists cooperated with other Department agencies in the preparation of a teaching kit "Food for Thrifty Families." The kit consists of an adaptation of the "Daily Food Guide" and a series of 20 fliers that contain information on nutrition and simplified recipes for donated foods and food relatively low in cost. The kit includes fliers on fruits and vegetables for vitamins A and C, and dry beans and peas.

A new bulletin "Vegetables in Family Meals" was added to the series of 11 being prepared to help consumers use basic food commodities. These bulletins bring together research findings on food preparation, selecting and buying food, food storage, nutrition, and menu and recipe suggestions for family meals.

The bimonthly publication of Nutrition Program News was continued. This publication reaches about 7,000 workers in nutrition and related fields. Talks to groups involved in community nutrition programs, radio tapes, and consultant help and participation in conferences contributed to coordinating and strengthening of nutrition programs.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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CITRUS AND SUBTROPICAL FRUIT

Southern Utilization Research and Development Division, ARS

Problem. The citrus and subtropical fruit production of the Southern Region is an expanding industry with the need for the development of better, as well as new-type consumer products, and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits, to the economic advantage of the growers and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils, flavonoids, including bitter constituents, constituents responsible for oxidized off-flavors, carotenoids, and the like, which determine many of the sensory characteristics, and which affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, fermentation, and the like. Increased production of citrus has stimulated the development of new products, but many of these are urgently in need of improvement which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change; to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products; comminuted whole fruit products; and to develop new or improved canned products which have a natural fruit flavor. Research is especially needed on grapefruit to develop practical methods for reducing the bitterness and harshness of juice products and to increase the use of grapefruit juice base in mixed fruit juice blends, drinks, concentrates, and the like. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials, to obtain and maintain the most desirable fruit characteristics particularly for citrus powders. In addition to the work on citrus, research is currently needed to develop new processed products from avocados.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on the chemistry of flavor of citrus and subtropical fruits and their products and byproducts is conducted at the U. S. Fruit and Vegetable Products Laboratory at Weslaco, Texas, and Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food products and processing technology. At the Weslaco Laboratory, the program includes

investigations of the influence of seasonal changes of carotenoid and flavonoid constituents which directly or indirectly affect flavor and color of processed products from Texas colored grapefruit, as a basis for improvement of processing characteristics of and products from these grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR, ARS, Weslaco), the Texas College of Arts and Industries, and Rio Farms, Inc. (Edcouch) are providing grapefruit of known history and conducting, or cooperating in conducting, on-the-tree tests. At the Winter Haven Laboratory, the program includes: research to identify recently isolated flavones and other neutral orange peel constituents and to evaluate their relation to bitterness and harshness in orange products; investigations of the composition of essential oils in citrus products, particularly orange, to provide a basis for improvement in quality and uniformity of citrus products; a study of off-flavor development in processed citrus juice in relation to the lipid composition of the suspended matter; and research to explore means for minimizing or blocking the formation of bitter components in grapefruit, a key step in developing processed grapefruit products of greater attractiveness to the consumer. Close consultation is maintained with the Florida Citrus Commission (Lakeland); the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred); Citrus Research Investigations (CR, ARS, Orlando); Florida Citrus Mutual (Lakeland); and the citrus processing industry.

Research to develop new and improved process and product technology is carried out at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas, and Winter Haven, Florida. At Weslaco, research is in progress to develop processed products from grapefruit and from avocados. The citrus and subtropical fruit research is being carried out in part in cooperation with several state and private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Formal agreements exist with the Texas Agricultural Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco), and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Canners Association (Weslaco), and such other organizations as necessary for the procurement and processing of fruit. At Winter Haven, conditions for the "foam-mat" type of air-drying as they relate to the storage stability and quality of the resulting citrus products are being studied. This research is conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding. Contract research on process and product development, supervised by the Weslaco Laboratory, is being carried out at the Citrus Experiment Station, University of Florida, Lake Alfred, Florida. It pertains to the development of a practical and efficient pilot plant scale process for the production of enzymatically debittered grapefruit juice and products with improved flavor, product stability, and storage characteristics.

The Federal in-house scientific effort at the Southern Division devoted to work in this area totals 11.9 scientist man-years. Of this total, 7.3 is devoted to research on flavor and 4.6 to technology-process and product development. The contract research involves an additional 0.3 scientist man-years on technology-process and product development.

The only line of work to be terminated during the year was the investigation of the effect of maturity of grapefruit on total flavonoids, naringin, and poncirin, and of the chemistry and nature of naringin and naringin-derived compounds to provide a scientific basis for the control of bitterness in processed grapefruit products (under Flavor).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 19.0 scientist man-years is devoted to citrus and subtropical fruit utilization research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Flavor

1. Chemical and Physical Properties of Flavoring Constituents of Florida Citrus and Subtropical Fruit Products. In the investigation of essential oils in citrus products, the alcohol analysis for Florida cold-pressed oils of grapefruit, lemon, lime, and tangerine has been completed. In addition to the 17 alcohols previously identified, three other alcohols were found in grapefruit. However, the presence of one of these compounds, o-phenyl phenol, may be explained by its use as a fungicide by the citrus industry. Since the alcohols in orange, grapefruit, and tangerine are very similar, the distinctive differences between the oils would not be expected in this fraction. The alcohols in lime and lemon are almost identical.

A procedure has also been developed for the separation of oxygenates other than alcohols. Although this procedure has not yet been perfected, it has been applied to orange cold-pressed oil with a good deal of success. It includes low temperature, reduced pressure stripping of limonene; column chromatography for the separation of the oxygenated group; and gas chromatography for isolation of individual components. In another facet of the research, gas chromatographically pure nootkatone was obtained from (1) cold-pressed grapefruit oil, and (2) the synthesis of nootkatone from valencene. The pure nootkatone was used in taste tests to determine its effect on the flavor in grapefruit juice. In addition to the above progress, mass spectra of all compounds submitted by the laboratory staff have been obtained. (S3 2-48).

2. Investigation of the Bitter Principle and Flavonoids in Citrus Products. In the continuing work on bitterness in oranges, an analytical experiment showed that the five flavones referred to in previous reports occurred in both the serum and the suspended matter of the concentrate investigated, some being more concentrated in one phase and some in the other. Evidently,

all of the flavor due to the neutral fraction can be accounted for by the flavones in the late season fruit but not in the early season fruit — re-evaluation of taste thresholds of the fractions gave the following results: December 1963, 17; January 1964, 23; March 1964, 29; early April 1964, 33; late April 1964, 31; and June 1964, 30. The five flavones gave threshold values as follows in ppm: tangeretin, 33; heptamethoxy-flavone, 28; nobiletin, 46; sinensetin, 30; and tetra-O-methylscutellarein, 15. All the above evaluations were carried out in a synthetic medium employed because of its reproducibility and the economy of flavones that could be detected at a lower level than in orange juice. These values should be useful in estimating the relative amounts required for evaluations of the compounds in orange juice and will also serve as a guide in later work. (S3 2-47).

Considerable progress has been made by the contractor, University of Oklahoma Research Institute, in determining the effect of grapefruit maturity on total flavonoids and on naringin and poncirin. In the 1964-65 season, the monthly variation in concentration of six flavonone glycosides in the juice sacs of Texas ruby red grapefruit was determined. These glycosides are naringin, naringenin rutinoside, neohesperidin, hesperidin, poncirin, and isosakuranetin rutinoside. The total flavonoid concentration decreased with maturity, but the ratio of bitter to nonbitter flavonones remained relatively constant. This finding failed to support a previously reported hypothesis that the decrease in bitterness of grapefruit may be the result of a transglycosylation that changes the bitter flavonones (7-β-neohesperidosides) to tasteless (7-β-rutinosides). Davis test values made on the same samples of fruit show a close correlation with the quantitative data for the flavonone glycosides, particularly the principal ones, naringin and naringenin rutinoside. Although the data have not yet been completely analyzed, they may indicate that bitter compounds other than naringin are involved in the decrease in bitterness of grapefruit with maturation, or that a nonbitter compound which appears in larger quantities in maturing fruit "masks" the bitterness of naringin. (S3 2-39(C) (Rev.)).

In research directed toward minimizing bitterness in grapefruit products, a new and more rapid method for the determination of naringin in grapefruit juice was developed. The results are available in four hours instead of the two days previously required, and the procedure is simple enough to be used by plant personnel. It is a modification of earlier procedures used for the separation of naringin (bitter) and naringenin-7β-rutinoside (tasteless), followed by their individual determination colorimetrically. The new method will aid in determining the effect of various possible inhibitors on the synthesis of naringin and on the seasonal variation of both constituents. It can also be used by the citrus industry to give an accurate and objective determination of naringin concentrations to be compared against subjective taste evaluations. Other work under this project showed that phenylalanine is a precursor to naringin in grapefruit. This was demonstrated by implantation of the radioprecursor into the phloem area of the stems, a technique that presently appears to be the

best means of getting labeled solids into the grapefruit plant. (S3 2-49).

Considerable progress has been made in a relatively new project designed to determine the influence of seasonal variations in flavor and color of Texas grapefruit on the quality of processed products. The study of the effects of environmental temperature on lycopene content of grapefruit has been completed. Grafted grapefruit on trees maintained in 95/85° F. day/night chamber remained green and increased in lycopene content throughout the 20-week period. Fruit in the 70/60° F. chamber lost its green color, yellowed, and declined sharply in lycopene content. Control fruit went through a normal increase and decline cycle. Establishing the fact that temperature is a major environmental factor in influencing the formation and disappearance of lycopene provides fundamental information by which growers and processors may be guided in the utilization of fruit at a time of optimum color.

Completion of tracer studies on grapefruit treated with $C^{14}O_2$ radioactive carbon dioxide at different times during the 1964-65 season has bracketed the period of maximum flavanone production as occurring during the first six weeks of fruit growth. More intensive tests are now in progress to evaluate quantitatively the period of flavanone formation. Improved methods of preparative and quantitative flavanone column chromatography that facilitate exact compositional studies have been developed. A number of minor polyphenol fractions that may influence processing and quality characteristics of grapefruit products have been found. Evaluation of a number of resins for column chromatography has shown polyvinyl polypyrrolidone to be superior for flavanone separation. Carbon was unsuitable because of incomplete recovery of absorbed materials. The completion of flavanone analysis of fruit from trees treated with a paraffinic oil spray has established that this cultural practice has no influence on flavanone composition of grapefruit. A method for the quantitative recovery of the limonoid compounds in grapefruit has been developed, employing continuous counter-current chloroform extraction of the depulped juice. The limonoids in the pulp are extracted separately with acetone. Taste tests on authentic limonin indicates that it contributes little to the total bitterness of Texas grapefruit products. Determination of various factors affecting flavonoid contents should lead to an improvement in characteristics of products made from colored grapefruit. (S3 2-51).

B. Technology -- Process and Product Development

1. Application of Foam-Mat Drying to Citrus. In research conducted in cooperation with WU and the Florida Citrus Commission, drying conditions of foam-mat powders are being studied with respect to storage stability and quality. Orange crystals made from concentrate which contained oil have a slightly better storage life than those made from concentrate without oil. Both develop detectable change in flavor in 4 weeks at 85° F. This coupled with analytical tests indicates that the oil acts primarily as a covering-flavor agent and does not retard the adverse

reactions occurring during storage. Several other furan and furfural type derivatives have been isolated and identified from "off-flavor" orange powder, providing more evidence of nonenzymic browning type reactions. Combinations of orange and grapefruit have resulted in crystal samples which have storage life improved over that of orange alone. Actual reasons for this increased stability are still being investigated. It has been found that algin derivatives are very useful for addition to low-viscosity orange concentrates to make them more suitable for foaming. This would indicate that viscosity is strongly related to the foaming characteristics of a concentrate. Expressions of interest from several commercial developers were evoked by promotional distribution of packets of grapefruit powder in an industry magazine. (S3 2-43).

2. Process for Enzymatically Debittering Grapefruit Products. After a six-month suspension of activity on contract research conducted on a pilot-plant process for enzymatically debittering grapefruit juice, work has again begun as bitter grapefruit have come into season. Experiments were conducted to determine the effect of high sugar concentration and sodium benzoate on the activity of naringinase. To commercial grapefruit sections, a 10% sodium benzoate and 40° Brix syrup was added. To this mixture, 0.1% naringinase was added and the product was held at 32° F. The presence of preservative on sugar syrup did not significantly interfere with the activity of the enzyme as it reduced naringin. Over 60% of the bitterness was removed after 5 days' storage and 79% reduction in naringin level occurred in about 30 days. Action on naringin was slower when lower levels of naringinase were added, but with only .005% naringinase, 10 days' storage reduced naringin by about 30% and 34 days' storage by slightly over 50%. Storage studies on these samples are continuing. Work has also continued on enzymatic debittering of pulp washed solids. Although naringin declined more slowly at cold storage temperatures than at high temperature, it is evident that addition of small amounts of naringinase (.005 - .010%) to products that are customarily stored for a number of days will cause a significant decrease in bitterness. (S3 2-46(C)).

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CITRUS AND SUBTROPICAL FRUIT

Western Utilization Research and Development Division, ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from almost all of the navel oranges, contains substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California; at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California; at the University of Hawaii, Honolulu; by contracts at Riverside and South Pasadena, California, and Tucson, Arizona; and, under a P.L. 480 grant, in Bogota, Colombia. Investigations are conducted on the composition of citrus essential oils, the flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, the enzyme systems that are involved in the appearance or disappearance of constituents and structures of plant tissues, and the constituents of dates that affect the quality and stability of products. The findings of such

research are applied in the development of new and improved citrus, tropical, and subtropical fruit products.

The Federal program of research in this area totals 19.0 scientist man-years, including contract research equivalent to about 1.6 scientist man-years per year and two scientists whose salary is provided under Memorandum of Understanding by the Lemon Products Technical Committee. Of the total, 7.4 are assigned to investigations on flavor; 5.2 on color, texture and other quality characteristics; 0.5 on microbiology and toxicology; and 5.9 on technology--process and product development. The Division supervises one research project supported by a P.L. 480 grant.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 19 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Flavor

1. Components of Aroma. Alpha- and beta-sinensal, which are unstable isomeric sesquiterpene aldehydes, were isolated from orange oil and shown to be important to natural orange aroma. These compounds have remarkably low odor thresholds (about 0.05 parts per billion in water)--very few compounds can be detected at such dilute concentrations. Nevertheless, they are the first compounds to be isolated from orange oil that impart a unique orange-like aroma; they obviously are important in the overall profile of orange flavor.

Gas chromatographic procedures have been further refined so that now more than 50 principal components of cold-pressed lemon oil can be analyzed without prior separation of the components into classes of compounds. Qualitative and quantitative evaluation of a great number of components can be made by feeding the effluent from a temperature-programmed capillary gas chromatograph directly into the ionization chamber of a time-of-flight mass spectrometer. These more rapid methods for analyzing whole citrus oils make it possible to establish standards to improve the quality of these products in commerce.

Nootkatone was identified as an important flavor component of grapefruit and its gross structure established as reported last year. Recently the stereochemistry of the molecule was investigated, and the stereochemical assignments given previously to nootkatone and its derivatives were confirmed. The orientation of the three-carbon side chain was determined to be equatorial, which completes the structure, relative stereochemistry, and absolute configuration of the molecule. This establishment of the complete constitution of nootkatone is essential to evaluation of its role in the flavor of grapefruit products.

Investigation of ways to stabilize flavor in tropical fruit concentrates is supported by a P.L. 480 grant to the Institute of Technological

Investigations in Bogota, Colombia. Volatile constituents of guava and curuba are being identified. Extracts of these fruits were analyzed for free acids by studying the methyl esters of the free acids with gas chromatography. Commercially produced tropical fruit products were chromatographically analyzed to measure freedom from contaminants. Several compounds, mostly esters, were synthesized for use as standards in evaluating tropical fruits. Tentative identity has been established for 40 components of guava and 18 of curuba. Recovery and concentration of guava volatiles has given products with aromas that closely approach the aroma of the fresh fruit. Concentrated recovered volatiles of guava and of curuba have been incorporated into several inert carriers (i.e., sugars, sugar mixtures, and sugar derivatives) and are now undergoing storage tests at several temperatures.

2. Citrus Bitterness. Basic research on the flavonoid constituents of citrus products has revealed much useful information about these components that are related to bitterness. Another type of compound, limonoid, is also involved in citrus bitterness. Three limonoids exist in significant quantities in navel orange juice, but only one of them, limonin, causes bitterness. Limonin has now been found, both in fresh grapefruit juice and in grapefruit juice products. This intensely bitter triterpenoid occurs in grapefruit juice samples at levels above its taste threshold. Past experiments with flavonoid debittering processes, based on treatment of grapefruit juice with naringin-hydrolyzing enzymes, were difficult to interpret because limonin had not been discovered in the juice, and the enzymes removed only the bitterness caused by naringin. The new discovery should lead to grapefruit juice that is less bitter, if we can develop appropriate new processes to remove limonin, or if new varieties can be bred in which limonin content is either very low or absent.

In contract research conducted by the Stanford Research Institute in South Pasadena, California, a satisfactory analytical method was developed for quantitative determination of limonin in navel orange juice. The procedure is sensitive, rapid and simple. When it was tested on several samples of orange juice of known limonin content, good recovery and low blanks were obtained. In orange juice prepared with known, very small amounts of limonin, recovery of limonin was 90% or better. The error we believe was largely due to mechanical loss of limonin during the extraction step. Interfering substances are negligible with this method of analysis. The new method should make it possible to determine routinely the limonin content of navel orange juice or to analyze oranges to determine whether or not their limonin content is so high that the juice made from them would not be salable. The bitterness of navel orange juice has long been known to be partly determined by the root stock on which the oranges were grown. Now, knowledge of the limonin contribution from various root stocks will be valuable in breeding new varieties and could lead to the development of a new non-bitter navel orange. The new method may be even more important for grapefruit juice. However, there are substances present in grapefruit which interfere with the analytical method to a much higher degree than is the case with navel orange juice.

Experiments were started to determine the metabolic paths that lead to the biogenesis of limonin. It is possible that ichangin may be a less bitter intermediate in the formation of limonin. Rutaevin, an oxidation product of limonin that is slightly bitter but not nearly as bitter as limonin, was isolated and its structure determined. A knowledge of the sequence of compounds that lead to the formation of limonin will aid in devising a method to control bitterness.

In grapefruit, naringin accumulates during the first few months of fruit development. After naringin ceases to accumulate, the fruit undergoes a three- to four-fold increase in dry solids. Our studies have shown that profound changes also occur in the pattern of polyphenols at the time naringin accumulation ceases. Thus, a biological mechanism seems to regulate naringin accumulation. This may be a further clue to eventual control of citrus bitterness.

B. Color, Texture, and Other Quality Factors

1. Citrus Carotenoids. We are investigating the chemical changes that occur in the yellow and orange carotenoid pigments of citrus fruit and its products. The major carotenoid constituents of desert grapefruit, lemons, and Valencia oranges are being isolated and characterized. In green fruit, carotenoids are subject to a degradation that is probably enzymic; however, there is a net synthesis of total carotenoids in both the endocarp and the peel of immature desert grapefruit. As the fruit ripens and the carotenoids decrease, esterified xanthophylls, which also are yellow pigments, increase. The ripe fruit, on disappearance of the green chlorophyll pigment, increases in carotenoids of the endocarp, while the peel shows a decrease in total carotenoid content. Changes in carotenoid pigments in the endocarp and peel of desert grapefruit show great variability during senescence and storage, that is, whether the grapefruit remains on the tree or not. We hope to trace the degradation of the complex carotenoid mixture of desert grapefruit to help us develop better methods for preserving color in grapefruit products.

2. Composition of Dates. We now know that the brown coloration of dates is the result of at least three different chemical pathways: (1) nonenzymic, oxidative browning of the insoluble leucocyanidin tannins; (2) enzyme catalyzed oxidative browning of the dactylifric acids, epicatechin and other water-soluble flavans; and (3) nonenzymic, nonoxidative, reducing sugar browning. In addition, when dates are heated higher than 140-160° F., an undesirable reddish discoloration develops. The red pigment may be caused by high-temperature conversion of leucocyanidin tannins. This knowledge that dates darken and discolor by a number of chemically distinct pathways is of considerable importance both scientifically and commercially. Processing conditions for dates can now be chosen to minimize darkening and discoloration of the fruit, and the information should be useful in the development of new processes and products. There is a very good chance that darkening of other dried fruits takes place by chemical pathways similar to those found in dates. Research on dates has been largely supported by the Date Administrative Committee of Indio, California. Financial support has been terminated, and research on dates is being continued under contract with the University of California at Riverside.

C. Microbiology and Toxicology

1. Pharmacology of Dihydrochalcones. The new methods for converting the bitter citrus flavonoids, naringin and neohesperidin, to intensely sweet dihydrochalcones may lead to commercial use of the new compounds as low-calorie food sweeteners. Toxicity levels of the dihydrochalcones have been determined by rat-feeding tests, and the promising results have been reported to interested industrial concerns. Two of the companies that hope some day to market these products have volunteered to prepare quantities of naringin and neohesperidin dihydrochalcones for further testing by the Pharmacology Laboratory of the Western Utilization Research and Development Division.

D. Technology--Process and Product Development

1. Citrus Products. Chemical methods are being developed to characterize lemon juice and lemon oil, and these methods are gradually being adopted by the industry and regulatory agencies for quality control and for determining authenticity of products. Rather large fluctuations were observed in the total amount of phenolic compounds of lemon juice--studies are underway to determine the cause. Chromatographic procedures were developed for quantitative estimation of individual polyphenolic compounds in hydrolyzed lemon juice. Since the total phenolic measurement is important in characterizing lemon juice it is necessary to know the individual components. Studies have been published on analytical methods for determining the total amino acid and total polyphenolics contents of lemon juice, and on the effects of fruit storage and processing variables on lemon juice composition.

The development and testing of new products from desert grapefruit are underway in contract research at the University of Arizona in Tucson. Combinations of grapefruit juice, guava juice, and grape juice appeared promising in preliminary studies, and samples have been stored for long-term stability testing. Taste panels indicate that diced grapefruit can be an acceptable substitute for sectioned grapefruit in salads. Such a substitution would materially reduce the cost of canned, frozen, and chilled grapefruit products. Studies are underway to enzymatically tenderize and debitter desert grapefruit to improve acceptability. Formulations are being tested to use grapefruit juice as an acidulant in salad dressing, canned nectars, and baby foods; as a browning control agent for french fried potatoes; and as an agent to inhibit enzymic browning of peeled fruit. When grapefruit juice was added to canning syrups, it imparted an improved fresh fruit flavor to canned apricots.

Foam-mat drying of fruit juices on a large scale is being studied at the Southern Utilization Research and Development Division at Winter Haven, Florida, with cooperation and support from the citrus industry in that state. Large runs of grapefruit juice have been made for use in market development tests. In-house investigations on foam-mat drying at the Western Division have been confined to demonstration runs to test the feasibility of dehydrating various fruit juices and other liquid foods.

2. Subtropical and Tropical Fruit Products. At our Hawaii field station, subtropical fruits are being concentrated and dehydrated to determine the processing quality of locally grown varieties of bananas, guavas, pineapple, papaya, and passion fruit, and to demonstrate processing methods that may aid in expanding local food industry. Two varieties of bananas were drum-dried, air-dried, or freeze-dried and then tested for storage stability. Analyses after one year storage have been completed. Storage temperature was an over-riding factor in rate of deterioration, although significant differences due to moisture content were observed. Low-moisture products (less than 4%) were more stable than high-moisture products (17-18%). Sulfur dioxide enhances the quality and stability of dried bananas. Mangoes were drum-dried to produce a good product, but other fruits appear to require special pre-drying preparation if drum-drying is to be feasible. Freeze-drying produced satisfactory products from all of the fruits tested. Quality of guava purée was improved by deaeration prior to freezing; deaeration also increased bulk density. Six months' storage at zero caused some color loss if the purée had not been deaerated. On thawing, the deaerated purée had less tendency to separate into pulp and a clear liquid than did the untreated sample. The separation of skins and seeds from papaya purée has been a major hurdle to developing a commercial product. We are working on a scraping devise that can remove the bitter skin from the flesh, and also on using standard pulper and finisher equipment to remove seeds from the flesh. Diversified fruit products will help stabilize the price of these fruits by reducing their perishability and making them available for shipment to markets away from Hawaii.

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DECIDUOUS FRUIT AND TREE NUTS

Eastern Utilization Research Development Division, ARS

Problem. Lack of knowledge of the nature and quantities of the various chemical constituents and enzyme systems present in fresh fruits, and of the changes these undergo during processing, is a limiting factor in research designed to develop new and improved products and processing techniques. Knowledge is required on the composition and physical structure of fruits and fruit products, with emphasis on substances responsible for color and flavor, vitamins, and other constituents important in determining consumer acceptance and nutritive value of the products. Composition should be studied in relation to variety, stage of maturity, and environmental conditions of growth; and to changes occurring between harvesting and processing, during processing, and in storage and distribution. Recently developed equipment and techniques have made it possible to isolate, separate, and identify constituents that could not have been handled previously. As basic information is developed, new processing techniques will be applied in the improvement of fruit products, and in more efficient utilization of by-products from fruit processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving chemists, biochemists, and chemical engineers engaged in both basic and applied research related to extending the use of fruits in the food processing industries. In the EU program apple products research, and investigations on the chemistry and cell structure of cherries are conducted at Wyndmoor, Pennsylvania. Development of rapidly-reconstitutable dehydrated fruit pieces is also underway at Wyndmoor. Contract research on apple texture is in progress at the Maryland Agricultural Experiment Station, College Park. Research on the metabolism of red tart cherries is being conducted under a grant at Temple University, Philadelphia. Contract research on peaches at Rutgers University, New Brunswick, has terminated.

The Federal (EU) scientific effort devoted to research in this area totals 8.6 scientist man-years. Of this number, research on chemical composition and physical properties constitutes 1.8, including 0.3 of contract research on apple texture at the Maryland Station and 0.3 under a grant at Temple University on the metabolism of red tart cherries, research on flavor amounts to 1.1, research on color, texture and other quality factors amounts to 0.3, including 0.1 of contract research on peach processing at Rutgers, and research on microbiology and toxicology amounts to 1.0. The remainder, 4.4 scientist man-years, is devoted to research on technology--process and product development.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 50 scientist man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties.

1. Post-harvest metabolism of cherries. The metabolism of specific C^{14}-labeled compounds injected into normal and bruised red tart cherries is being studied under grant research at Temple University. The supplies of fruit for this purpose are being carried in frozen storage. Research is under way to develop procedures for separating the various constituents of raw cherries. Alcohol extraction provides a solution which has been separated by column chromatography into fractions of sugar, organic acids and amino acids. Known procedures will be adapted for separating the alcohol insoluble fraction into components such as pectin, lignin, hemicellulose and cellulose.

2. Factors influencing apple texture. Contract research at the Maryland Agricultural Experiment Station, College Park, shows that calcium ion reacts with both pectin and hemicellulose during apple processing. The calcium content of the pectin and hemicellulose fractions was closely correlated with the firmness of the processed slices. There was also some evidence that reaction of calcium ion with cellulose may be important in fruit stored over 75 days. The finding that calcium reacts with pectin and hemicellulose provides a basis for explaining the calcium firming treatment widely used in improving texture of apple slices. Research continued on the identification of various cell wall components of raw and processed apple tissue.

B. Flavor.

Components of cherry essence. Continuing research on the separation and identification of the components of 150-fold cherry essence shows the occurrence of acetaldehyde and methanol. Other compounds have been isolated but are not yet identified. Since atmospheric fractional distillation did not excessively degrade cherry flavor, it provided a more convenient method for the concentration of the low-boiling components than did vacuum distillation. Removal of the low-boiling components provides an essence concentrate which retains some of the constituents characteristic of cherry flavor.

C. Color, Texture and Other Quality Factors.

New varieties of fruit. As a direct result of contract research (now terminated)at the New Jersey Agricultural Experiment Station, the outstanding processing quality of the Babygold series of nonmelting clingstone peaches was discovered and brought to the attention of processors. This has led to a new industry in Eastern North America.

About one million trees of the Babygold varieties have already been planted in ten states and in Canada. They will be canned as halves in western Michigan and in Virginia's Shenandoah Valley and, it is presently planned, as puree in southern Ontario, Arkansas, and the Carolinas.

A freestone peach, Red Queen, of excellent flavor and acceptable in texture when canned or frozen, will be used as a parent in the Station's peach-breeding program.

A new variety of nectarine, NJN 32, is especially promising as a source for providing a good frozen product.

Genotypes of selected new varieties of peaches and nectarines will be made available to plant breeders, growers and processors.

D. Microbiology and Toxicology.

Improved apple cider. The effective preservation of apple cider by either refrigeration or "sorbate" depends on a low initial microbial count. Either the addition of diethylpyrocarbonate to fresh apple cider or the process of irradiation of the cider with ultraviolet rays is a relatively inexpensive procedure and a promising method for destroying most of the viable microorganisms in the fresh cider.

E. Technology--Process and Product Development.

1. Explosion-puffed fruit. The improved puffing gun which makes use of superheated steam to supplement external heating has shortened the cycle and increased the capacity to a level adequate for commercial operations. Blueberries at 11-18% moisture were satisfactorily dried to 4% moisture with, however, some breakage of the berries. It was found more desirable to dry to a moisture content of 8%. With 25-pound charges and a 4-minute cycle, output at 8% moisture is about 330 pounds per hour for one puffing gun.

A 300-bushel lot of York Imperial apples has been sampled weekly for pilot plant experiments on explosive-puffing. The firmer apples taken from storage early in season show less disintegration on puffing, but rehydrate more slowly. After long storage the apples are softer and disintegrate more on puffing but rehydrate more quickly. With apples of proper firmness and with the use of superheated steam, which reduces the time required for heating in the gun to one minute, excellent pie slices and snacks have been made.

2. Processing of red tart cherries. Progress was made in the maintenance of processing quality of red tart cherries during mechanical harvesting of the 1965 crops. Mechanical harvesting of cherries has increased from 3 million pounds in 1963 to more than 25 million pounds in 1965. A development instigated by laboratory studies on bruising is retention of the freshly harvested cherries in their original orchard soak-tank while being brought to the cannery. The cherries are funneled directly from the tank into the processing line. Changes in handling and in processing line procedures to minimize bruising of the cherries are expected to provide a product of improved quality.

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For related publications of State Experiment Stations on Deciduous Fruit and Tree Nut Utilization - Food see the Summary of Current Program and Preliminary Report of Progress from the Western Utilization Research and Development Division, Area No. 7, or Southern Utilization Research and Development Division, Area No. 11.

DECIDUOUS FRUIT AND TREE NUTS

Southern Utilization Research and Development Division, ARS

Problem. The peach industry in the Southeastern United States is dependent to a large extent on the fresh market. For example, 19,405,000 bushels of peaches were produced in the South Atlantic and South Central States in 1965; of this total, 13,188,000 bushels from both areas were sold on the fresh market and only 2,846,000 bushels--none of which were grown in the South Central States--were processed. A peach processing industry is needed in the Southeastern States to provide a profitable market for more of the edible peaches that do not meet fresh market standards and to rapidly convert a higher proportion of the overall crop to stable forms. Basic information, not now available, on the flavor components of peaches is needed to guide development of improved processed products from southern grown fruit.

Climatic conditions that favor rapid deterioration of fresh peaches both on and off the tree, erratic ripening periods and markets, and short-lived peach orchards are other factors contributing to the need for more extensively integrated fresh market-processing operations. Technical problems preventing the more rapid development of the peach processing industry in the Southeastern States must be overcome. Many of the peach varieties grown in the Southeast require a modification of processing procedures to make satisfactory standard-type products. Still other varieties cannot be used in standard-type products, and new food forms must be found for them. Recent rapid advances in food science and processing technology make it possible through research to develop both new and improved peach products. These are needed to bolster the economics of the South's peach industry, as well as to provide the superior qualities and greater convenience in food products, which the consumer now demands.

USDA AND COOPERATIVE PROGRAM

The Department has a program of basic research on peaches being conducted under contract by the Georgia Agricultural Experiment Station, University of Georgia, Experiment, Georgia. Food chemists and food technologists conduct this research. Research to develop basic information on the flavor of peaches, particularly varieties grown in the Southeastern States, is in progress under one contract. Specifically, the objective of this research is to isolate, identify, and characterize the constituents of peach flavor and aroma, and to acquire information needed to guide development of improved processed products from the fruit.

The contract research involves a total level of effort of 0.5 scientist man-years, all of which is devoted to an investigation of flavor.

One line of work (under Technology--Process and Product Development) was discontinued during the reporting year. Conducted by the same contractor,

Georgia Agricultural Experiment Station, it concerned research on optimum procedures for the production and preservation of puree and clear juice peach concentrates, for the preparation and the handling under simulated commercial conditions of refrigerated fresh peach slices, and for canning Southeastern peaches; and on the development of partially dehydrated pasteurized peach products. This research was carried out with the support of the Area Redevelopment Authority of the Department of Commerce.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 50.0 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Flavor

1. Basic Studies on Flavor and Odor Constituents of Peaches. Analysis of the flavor and aroma constituents of Southeastern peaches is being conducted under contract to the Georgia Agricultural Experiment Station. Gas chromatographic procedures were used to analyze the sugars (trimethylsilyl derivatives) from Coronet, Southland, and Sullivan Elberta peaches at three stages of ripeness. It appeared that sucrose was predominant (57-74%) in all three varieties and at all different stages of ripeness. In general, fructose and glucose were comparable except for Sullivan Elberta peaches, in which fructose increased through the shipping ripe, firm ripe, and soft ripe stages, while glucose, in contrast, decreased. For Coronet peaches ripened off the tree, great decreases in mannose and fructose were found. Other compounds noted were galactose and sorbitol. Studies are continuing to identify the volatile constituents present in an oily residue isolated from fresh peaches. Among compounds tested, gamma decalactone, ethyl heptylate, ethyl acetate, and ethyl acetoacetate agree in retention time with peaks from the peach oil, but more work is needed to positively establish their presence. The oil residue of fresh Sullivan Elberta gave different peak areas according to the degree of ripeness. The most significant change was the increase of peak area in the compounds with a long retention time in firm ripe as compared to shipping ripe. These observations together with others may indicate that as the peaches become riper the amount of high molecular weight compounds increases. (S3 2-44(C)).

B. Technology--Process and Product Development

1. Development of New and Improved Processed Products from Southeastern Peaches. Valuable technical information on the development of new and improved processed products from Southeastern peaches has been obtained in recently completed contract research conducted by the Georgia Agricultural Experiment Station. Peach puree. A process has been developed for the manufacture of a puree-type peach drink of twofold strength, and for

the bulk manufacture of peach puree vase for drinks and "concentrates." Clear peach juice and concentrate. A process has been improved for the manufacture of a clear peach juice and concentrate. This product can profitably utilize the 10% to 25% of the total production of peaches that fails to meet standards for shipping fresh, canning, pickling, or use in peach puree products. Refrigerated fresh peach slices. A process has been improved for the manufacture of refrigerated fresh peach slices without pasteurization treatment. Canned peaches. The extensive data obtained will be helpful in raising the U. S. Standard Grade of canned Southeastern peaches. These data include effects of early-, mid-, and late-season varieties, stage of maturity, preprocessing treatment, canning medium, and the like. Dehydrated peach flakes. Limited samples of the product developed in cooperation with SU have been prepared for evaluation and distribution. Other. Additional progress achieved under this contract includes a demonstration of (1) the potential of the gas chromatographic profile for ready detection of quality differences in peach products, and (2) the wide variance of total tannins, leucoanthocyanins, and flavonols in different varieties, and their gradual increase as the fruit matured. These products and results should augment the utilization of Southeastern peaches. (SU-0-0-1 (DC)).

PUBLICATIONS - STATE EXPERIMENT STATION

None

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DECIDUOUS FRUIT AND TREE NUTS

Western Utilization Research and Development Division, ARS

Problem. Fruits and nuts are valued for their unique flavor, color, and mineral and vitamin content. In the period of abundance at harvest time, markets are glutted and growers often do not get an adequate return. Crops are perishable, and processing to preserve their unique qualities is difficult. No processed fruit retains completely the fresh values, although many highly acceptable products exist and about half of the fruits and nuts marketed in the United States are processed. Processing makes these commodities available to consumers the year around, and has opened new markets for producers. The proportion of processed commodities is steadily increasing but is dependent upon a continuing flow of new knowledge. Processing to preserve color, flavor, texture, and nutrients presents many problems, and each new product requires the application of much scientific and technological skill.

The continued supply of preserved fruits is largely dependent upon relatively inexpensive sources of raw material. Decreasing supply and increasing cost of harvest labor is leading rapidly to the development of mechanical harvesting methods. Mechanical harvesting does not allow the sorting and careful handling of traditional hand picking. The processor must deal with trash, and bruised, cracked, immature, and over-ripe fruit along with prime quality. Research is necessary to develop new processes and products to reduce costs and utilize such raw material in the processing plant.

The freezing process for preserving certain fruits keeps products at near fresh fruit condition, but many problems remain unsolved. The enzymatic browning of frozen peaches and the sloppy texture of frozen strawberries on thawing are two examples.

Frozen fruits require expensive low-temperature storage and transportation facilities. This expense can be greatly reduced by removing a portion of the water from the products. Orange and other fruit juice concentrates are well established in U.S. markets, and dehydrofrozen apple slices (rapid drying to 50% bulk weight and then freezing) are just becoming well established. Many other fruits and fruit juices should be amenable to concentration. Any frozen product, however, is not as well adapted for export as those which do not require refrigeration.

Maximum weight reduction, as well as less restrictive storage requirements, can be achieved through dehydration. The drying of fruit juices has been successfully accomplished by the vacuum puff drying and foam-mat drying processes. New methods are being developed to dehydrate pieces of fruit with excellent retention of color and flavor. Extension of laboratory procedures to pilot- and commercial-scale operations must still be done. Flavor recovery and the incorporation of recovered flavor in solid carriers

for addition to the dried products require technological and basic chemical study. Aroma recovery techniques developed for fruit juice concentrates are being improved but require more work. Dried fruits are now widely used in the U.S. and abroad. Their popularity would grow if stable, higher moisture dried fruits were available and if lower levels of sulfur dioxide could be used without loss of quality.

Container costs for canned fruits limit the shipment of these products overseas. A solution of the container problem may be found in the use of lightweight fiber, foil, or plastic containers and aseptic filling procedures.

Fruit growers need new varieties of tree fruits and berries suited to processing and resistant to diseases endemic to each region of production. Utilization research is required in cooperation with farm research to assure growers of a market for fruit in the processing industry.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a broad program of basic and applied research on deciduous fruits and tree nuts is conducted at the Division headquarters at Albany, California; in field stations at Pasadena, California, and Puyallup, Washington; by contracts in Davis and Los Angeles, California, Fort Collins, Colorado, Geneva, New York, and Chicago, Illinois; and by grant funds under P.L. 480 in Israel, Taiwan and India. Fundamental research is conducted on fruit constituents associated with flavor, color, and texture of fruit products. The work includes development of laboratory tools to isolate and characterize components, investigation of such components as they occur naturally and as they are altered by operations involved in preservation, and study of the relationships between the components and the product values being preserved. Applied research is conducted to develop new and improved processes and products that will increase utilization of fruits and tree nuts, including the development of high-quality concentrated and dehydrated products and more stable shelled tree nuts and the selection of improved processing varieties. Pioneering research on plant enzymes is also conducted.

The Federal program of research in this area totals 35.7 scientist man-years, including two scientists whose salaries are provided by two cooperators (Dried Fruit Research Advisory Committee, whose membership represents the California Raisin Advisory Board, the Dried Fig Advisory Board, the California Prune Advisory Board, and the Dried Fruit Association of California; and the Walnut Control Board - one each) under Memoranda of Understanding; and six grants and contracts providing research at a rate of approximately 3.9 scientist man-years per year. Of the total number, 0.6 are assigned to investigations on chemical composition and physical properties; 7.7 on flavor; 13.3 on color, texture and other quality characteristics; 3.3 on microbiology and toxicology; and 10.8 on technology--process and product development. In addition, the Division sponsors basic research on fruit by means of four P.L. 480 grants.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 50 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Walnut Fatty Acids. Precise measurement of fatty acids in oils obtained from fresh walnuts and from kernels that had been subjected to accelerated storage revealed no difference in these components although the stored samples were damaged severely from an organoleptic standpoint. If, as has been generally assumed, oxidation of unsaturated fatty acids in lipids is responsible for rancidity of stored walnut kernels, the oxidation must be of only minute amounts of any of the major fatty acids. Or perhaps some unknown minor constituents are intimately involved in rancidification. High-resolution micro-preparative gas chromatography techniques have been developed to isolate highly purified compounds in microgram quantities. The isolated material can be carried to other locations for micro-analyses such as mass spectrometry and infrared spectrometry. These microtechniques permit a fast comprehensive study of chemical changes in major and minor lipid constituents of walnut oil and an evaluation of their roles in the development of rancidity.

2. Alleged Allergenicity of Chlorogenic Acid. Chlorogenic acid is a common component of fruits and most other plant materials. Research elsewhere on the allergy of green coffee beans led to a series of publications that implicated chlorogenic acid as the allergenic substance giving intense immediate skin reactions. Using allergic serum transfer tests in non-human primates and cooperating in tests with human volunteers, we have rigorously tested this hypothesis. We did not find chlorogenic acid to be an allergen in human atopic hypersensitivity. However, antigenic properties were observed in the protein-containing fraction of green coffee beans. Chlorogenic acid isolated from fruit elicited no allergic reaction, either.

B. Flavor

1. Methods and Equipment. Collection of purified samples from gas chromatograph effluents has been made more efficient and simple by using Teflon tubes for 1-mg. quantities and stainless-steel wool in glass tubes for 100-mg. quantities. Relative retention times with various stationary liquids have been studied to determine quantitatively the interaction between solute and solvent. With the information obtained, we now can choose logically a satisfactory stationary liquid for separation of specific mixtures, to make more efficient columns, and provide better resolution.

Large numbers of esters are found in fruit volatiles. Isomers are difficult to separate, so spectroscopic data and organoleptic descriptions that would be helpful in providing a better understanding of fruit aroma are meager.

To attack this problem, we obtained the 8 pentyl acetate isomers and cyclopentyl acetate from commercial sources or by synthesis, and rigorously purified them by preparative gas chromatography. Then we determined the purity of each sample by high resolution analytical gas chromatography, and obtained and recorded the infrared proton magnetic resonance and mass spectra of each. Taste panels evaluated each sample for threshold and made discrimination determinations. Odor thresholds ranged from two parts per billion parts water for 2-pentyl acetate and 3-methyl-1-butyl acetate to 30 parts per billion for 1,1-dimethyl-1-propyl acetate. Although most of the compounds were given the general qualitative odor description of fruity-floral, the panel was reliable in distinguishing a difference between the individual isomers.

2. Fruit Volatiles. Three varieties of grapes (Concord, Muscat of Alexandria, and Grenache) have been analyzed by gas liquid chromatography-mass spectrometry. Of the many volatile components from Concord grapes, 16 have been identified. Ethyl acetate and ethanol were found in greatest quantity; the next most abundant component was 2-methyl-3-butene-2-ol. Other components are being identified. Some 60 components have been identified in the volatile constituents of the juice of Muscat of Alexandria grapes. Several components, including propyl benzene, 3-methyl-biphenyl and diphenyl ether, are unique to this fruit or have been overlooked in similar research with other fruits. The flavor and aroma of the muscat grape is considered unique, and these unusual volatile components may be a reflection of this distinct characteristic. Similar methods have been used to investigate the fruit volatiles of Grenache grapes. Hexanal was by far the largest constituent of the oil obtained when a 100-fold essence from free-run juice was extracted with isopentane and partitioned between propylene glycol and isopentene. Large amounts of isomers of amyl alcohols and other alcohols were obtained in addition to a large number of aldehydes, ketones and esters.

Organic volatiles were extracted from 150-fold red Delicious apple essence, and fractions separated by gas liquid chromatography. Taste panels sniffed a portion of the column effluent to identify fractions with characteristic apple and apple-like aroma. Relative odor intensities of these fractions were determined by threshold concentration measurements. Of four important fractions, the one with the most intense odor was present in the lowest concentration. Apple essences which had been held for one year at different temperatures lost significant amounts of certain components as measured by area under gas chromatograph peaks.

Research aimed at developing better and more uniform flavor in canned ripe olives is being conducted by contract with the National Canners Association's Western Laboratory in Berkeley, California. Olive samples designated by industry spokesmen as having certain typical off-odors were assembled and evaluated at eight processing plants. Industry tasters gave significant off-flavor assignments to only one sample which contained an excess of ferrous glucanate. Other samples judged as off-flavor by some were not so designated by others. Analyses of these samples were made for six compositional factors: volatile fatty acids, squalene, polyphenols, total tannins, iron, sodium, and

volatile carbonyl compounds. Olive samples judged good in flavor had methyl ketone content of less than 2 parts per million. Olive samples described as having bitter, storage, or Zapatera off-flavor had methyl ketone content of 2.5 to 17 parts per million. Experimental packs of Manzanillo olives were made and processed after different storage periods in brine. Only four samples that had been in the brine for 15 and 20 weeks were distinguished by a trained laboratory taste panel as being different from the other samples. No difference was found among four samples which differed in final pH over a range of 9.05 to 7.13. Volatile carbonyl content increased rapidly in the brine during the early part of storage and then decreased as storage time lengthened. In experimental packs of olives, no significant correlation of product flavor with volatile methyl ketones was observed, although such a finding appeared in several lots of commercially packed olives.

C. Color, Texture and Other Quality Factors

1. Fruit Pigments. Cooperative studies conducted with the Crops Research Division have demonstrated that color hue and shade, and also stability of anthocyanin pigments, are dependent upon four factors: (1) a particular anthocyanin pigment; (2) a complexing metal salt, such as aluminum or ferric ion; (3) a phenolic co-pigment such as chlorogenic acid, quercetin, or catechin; and (4) an acid that will not compete with a metal ion in chelation with the co-pigment. It has long been known that the colors of many red and blue fruits and flowers are due to anthocyanin pigments. A typical pigment would be red in acid and blue or purple in a more basic solution. However, it has not been possible to explain the blue color at physiological pH of fruits and vegetables, nor to account for the stability and intensities of the colors at the natural pH levels. The pigmentation of hydrangea flowers may be used as an example of anthocyanin reactions. Both red and blue hydrangea blossoms contain the same anthocyanin pigment and undoubtedly the same co-pigment. In the blue flowers, an insoluble complex accounts for the color. In the red flowers, either insufficient metal is present or it is unable to chelate with the co-pigment because of the competitive action of citric or tartaric acid apparently not present in the blue flower. Similar mechanisms probably influence color and color stability of purple and red grapes, plums, and berries.

Investigation of the natural tannins and leucoanthocyanins in fruits is being conducted in contract research at the University of California at Los Angeles. Dimeric proanthocyanins of the avocado are composed of two flavan monomers containing 15 carbon atoms each. The reaction mechanism of this dimerization is being investigated by means of a model system involving methylation and reduction of dihydroquercetin.

The phenolic components of apple juice that complex with proteins and settle out of clarified juice are being investigated in contract research at Colorado State University. Extensive analyses of apple juice and sediments obtained by accelerated storage were made. The sediments were demonstrated to be a complex of protein and oxidized polyphenolic compounds. The loss of

phenolic constituents from the juice during accelerated storage could be followed by thin-layer chromatographic analyses. Sulfite and ascorbic acid added as antioxidants during milling and pressing of apples did not prevent sedimentation of clarified juice. Mineral analysis of the sediments showed the presence of calcium, magnesium, copper, iron, potassium and sodium, indicating a heterogeneous nature of the sediment. Leucoanthocyanidins and catechins were found to be the principal precursors of the phenolic components of the sediment. Chlorogenic acid did not appear to be involved.

The phenolic substrates of enzymic browning of fruits and the methyl-transferring enzymes that alter the substrates to prevent them from turning brown are under continuing investigation. To obtain information on stability and specificity, we have used exchange resins and dextrin gels to purify plant catechol O-methyltransferase. With carbon-14 as a tracer, we are determining methyl transfer in biosynthesis of methylated constituents of plants. Control of native methyl transferase in apples by temporary alteration of surface pH allows phenolic browning substrates to methylate so that apple slices can be preserved for two to three weeks under refrigeration. With this means of color control, apple slices remain crisp. If color is protected only by sulfur dioxide, two adverse side effects are the presence of a sulfite flavor and a loss of cell turgor and crispness. A commercial processor in Wisconsin has followed our suggestions and is applying our process to the preservation of peeled and sliced apples and cored apples for the restaurant and bakery trade.

Research at the University of Delhi in India is supported by P.L. 480 funds to determine the role of leucoanthocyanins in the development of natural pigments and the darkening of deciduous fruits during processing and storage. Two anthocyanins were extracted from plum peels and shown to be derivatives of pelargonidin. No other polyphenols were obtained from the methanolic hydrochloric acid extracts. Similar extracts from peels of three varieties of red apples were found to contain pelargonidin and two flavonoids. Two leucopolymers were obtained from grapes; one turned blue in the presence of ferric ion, the other remained unchanged. The one with the blue reaction was shown to be a derivative of leucopelargonidin. The seeds of the grapes also were found to contain leucopelargonidin.

P.L. 480 funds support an investigation of enzymatic browning in deciduous fruits at the Hebrew University in Jerusalem. The activity of phenolic oxidase enzyme activity was followed in developing apples from fruit set to harvest time. O-diphenyls had peak concentration early in the fruit development; at maturity the concentration drops, apparently because they are converted to other compounds or synthesis stops. Catechol oxidase activity shows a peak after that occurring for the enzyme of O-diphenyls. As the fruit ripens, activity drops sharply, and in the ripe apple only a slight amount of soluble enzyme is found. Findings were correlated with the rate of browning of apple slices and the location of enzymes and their substrates in fruit. A number of apple varieties were compared for keeping quality, O-diphenyl content, catechol oxidase activity, and rate of browning of slices.

Good correlation between browning and O-diphenyl content was found and some correlation between browning and enzyme activity at pH 7.3. Purification of enzymes present in apples, peaches, and apricots is in progress. Several of the enzymes isolated from peaches were studied for their activity, their inhibition by various compounds, and their pH optima.

2. Cell-Wall Structure and Texture. A research grant to Harvard University on cell wall structures has been concluded. An organization of cell cytoplasm that appears to be associated with active cell-wall production has been demonstrated with the electron microscope by applying special fixing techniques developed at the Harvard laboratory. The grantees were able to show that microtubules are always found directly below zones of heaviest cell-wall deposition and that they govern the orientation of cellulosic microfibrils along the wall. This concept of the mechanism of cell-wall formation is entirely new. Cell walls vary widely in different fruits and different parts of fruit, and play an important role in the texture of fruit, drying rates, and stability in freezing and thawing.

Investigations on the formation of hemicellulose as plant cell-wall constituents are being conducted at the National Taiwan University in Taipei, Taiwan, China, supported by P.L. 480 funds. Texture of processed fruits and vegetables is largely determined by the chemical and physical properties of polysaccharides associated with cell walls. Bamboo shoot has the remarkable property of withstanding severe cooking conditions without losing crispness. Because of this characteristic the hemicellulose fraction of bamboo shoots is under study. Starch and pectic substances have not been found in the bamboo shoot. Sucrose serves as the reserve carbohydrate in place of starches, and hemicelluloses appear to constitute the bulk of the cell wall polysaccharides. The hemicellulose fraction consists of two polysaccharides, a galactan and a xylan. The xylan is more closely associated with cellulose than is the galactan, and no proteinaceous material appears to contribute to textural quality in the cell wall fraction. The absence of water-soluble polysaccharide in bamboo shoots appears to have a great bearing on the textural quality. However, the absence of intercellular cementing polysaccharides, such as pectin, raises the question of what material or force keeps the integrity of texture even under severe heating conditions. The chemical and physical properties of hemicelluloses, the biochemical mechanisms by which they are synthesized, and the nature of their association with cellulose are being studied to learn the reason for the textural quality of this product.

3. Pioneering Research. Within the Western Utilization Research and Development Division, a Pioneering Research Laboratory conducts basic research to discover, identify, and characterize the enzyme-substrate systems responsible for formation and disappearance of plant constituents and structures.

Ethylene Metabolism in Plants. Last year this Laboratory reported that the metabolism of either labeled ethylene or labeled acetylene results in the formation of radioactive benzene and toluene. It became apparent that benzene and toluene occur, as such, in mature but unripe avocados. Now fruit has been exposed to small amounts of C^{14}-labeled benzene and toluene. Both of these hydrocarbons were rapidly metabolized. A small portion of both were metabolized all the way to CO_2. Volatile and nonvolatile metabolites were formed from the benzene and toluene along chemical routes similar to those observed with ethylene and acetylene. When fruit was exposed to unlabeled benzene and toluene, large concentrations in the surrounding atmosphere and long exposure times were required to produce any visual effect on the fruit. Again, rapid metabolism of these hydrocarbons in avocado was indicated. Work will continue on the separation and identification of products formed in fruit exposed to benzene and toluene as well as to ethylene, so as to elucidate the mechanism by which ethylene exerts its effect in the acceleration of ripening.

Enzymatic Mechanism for Replication of DNA. Information for the biosynthesis of enzymes resides in informational molecules, which are nucleic acids, particularly deoxyribonucleic acid (DNA). This compound is present in the nucleus of all living cells. Since all enzymes for which DNA is coded are not made all at the same time, a mechanism must exist by which only those enzymes needed at a particular point in the life cycle of a cell are made at the right time, and the synthesis of those enzymes not needed is prevented. Good candidates for the agents that suppress transcription of information from DNA are the histones, basic proteins associated with DNA as complexes called "nucleohistones." Not all of the DNA is so complexed. From our current work it appears that the transcription of information for making enzymes can be accomplished only by that part of the total DNA which is not complexed as nucleohistone.

In addition to transcribing information for making enzymes, DNA must also transmit this information to succeeding generations. It does so by replicating itself. Last year we reported that nucleohistone as well as free DNA could serve as a template for the replication of DNA by an enzyme system of bacterial origin. Now for the first time DNA polymerase has been detected in higher plants, in the sprout (seedling) of the mung bean (used commercially in Chinese foods). The enzyme appears to be concentrated in the roots. Its activity on a fresh weight basis is about one-tenth that of bacteria. Thus it appears, as predicted, that the enzyme is made in response to the DNA requirement of the cell.

Enzyme Localization in Plant Cells. Characteristics such as flavor and texture are built into fruits and vegetables by a series of organized enzyme

reactions. In order to control desirable characteristics as well as to eliminate undesirable ones, basic information on the cell mechanisms involved in the induction and repression of enzyme formation is needed. To approach this problem, work has begun on the localization and changes in enzymes which occur in plant tissue cultures (from tobacco plants) where it is possible to work at the cellular level. Cells are propagated by transferring aliquots of an old culture to fresh medium where they continue to grow and divide.

Certain morphological changes occur during growth of a culture, most notably a rapid initial proliferation of new small cells which eventually enlarge as the culture ages. In addition, we find changes in the localization and distribution of enzymatic activity in the cells which are independent of morphological changes at the light microscope level. Thus, for example, certain oxidases (cytochrome oxidase and peroxidase) and dehydrogenases (succinate, malate, glutamate, glucose-6-phosphate, ethanol) are characterized by a shift in localization pattern during the period between inoculation and senescence of the culture (about 2 weeks). Specific enzymatic activity has been shown to rise and fall in cyclic patterns during the growth period.

Patterns of activity are temperature-dependent. Thus, for example, growth cell morphology, enzymatic activity, starch storage capacity, and mitochondrial size and shape are altered by changing the growing temperature from 25° to 35° C. Electrophoresis studies of peroxidase activity from cells grown at 25° and 35° suggest the possibility of an altered enzyme or two different peroxidase enzymes, one operating at 25° and one at 35°. These studies have demonstrated the unique and special sites in plant cells where enzyme activity occurs and some of the factors that influence the level of activity. From this kind of information it may one day be possible to optimize the kind of enzymatic activity desired and, moreover, to predict activity based on appropriate selection of conditions. Accordingly, this work is being continued.

Biochemistry of Plant Steroids and Related Polyisoprenoids. In cooperation with the Division of Biology of the California Institute of Technology, the enzymatic synthesis and interconversion of plant steroids and related compounds, as well as the chemical reactions of these substances, are being studied with special attention to the manner in which these compounds may function as plant hormones.

Steviol, a diterpenoic acid, occurs in the form of its glucoside, stevioside, in a South American shrub. Stevioside is the sweetest natural compound known. In the past steviol has been tested for biological activity in plants. In one plant, a mutant, it exhibited gibberellin-like activity, thus suggesting that this mutant might possess the ability to convert steviol to a gibberellin. In the present investigation, this possibility was shown to be true.

To pursue this research it was first necessary to have radioactive steviol. The tracer steviol was obtained by feeding Stevia plants radioactive acetate. Strangely enough, feeding labeled mevalonic acid failed to produce labeled steviol, which is counter to the known biosynthesis of other terpenes, and suggests the existence of another enzymatic system for terpene synthesis.

The tracer steviol was converted to a gibberellin by incubating it with a Fusarium mold. The resulting compound was effective on many plants. Isolation of the new gibberellin and characterization thereof showed it to be different from nine known gibberellins. Its precise chemical nature has not yet been established; research is continuing.

Conflicting reports have appeared concerning the occurrence of the female sex hormone, estrone, in palm seeds. In the present research, estrone has now been isolated and identified, not only in seeds and pollen of the date palm but also in pomegranate seeds.

In addition, cholesterol has been isolated in crystalline form from the date pollen. This is the second time this research group has isolated cholesterol from a plant source. Previously, it was thought to occur only in animal tissues.

We have also shown that cholesterol is a precursor of many plant steroids. It is converted in certain plants to the sapogenin, diosgenin, as well as to the latter's analogue, kryptogenin. It also functions as a precursor of plant steroidal alkaloids like tomatidine and the Holarrhena alkaloids, holaphylline and holaphyllamine, as well as the female hormone, pregnenolone.

Like cholesterol, β-sitosterol, the most widely distributed sterol of higher plants, is formed biosynthetically from the triterpene squalene.

The relationship between gibberellins and anti-gibberellins (plant-growth retardants) has received some attention. The latter have been presumed to function via interference with the synthesis of the former. This mechanism has been confirmed by use of the fungus Fusarium. Cultures of this fungus convert mevalonic acid (a biosynthetic precursor of many isoprenoids) to gibberellins in the absence but not in the presence of the anti-gibberellins.

The study of the enzymatic synthesis and interconversion of plant steroids and related compounds will be continued with special attention to their possible role as plant hormones.

Chemical Alteration of Enzymes. Chemical modification of pure crystalline enzymes in order to locate active regions in protein molecules and to determine relationship of molecular structure to enzymic activity has been investigated by a collaborator with the Pioneering Research Laboratory whose research was supported in part by a grant from the National Institutes of Health.

As previously noted, the acetylated chymotrypsin obtained by directly acylating the enzyme differs markedly from that resulting from activation of already acetylated chymotrypsinogen. In the latter case, the esterolytic activity is greatly enhanced over that of the directly acetylated protein and is usually much greater than the activity of the original (unacetylated) enzyme; the proteolytic activity is not correspondingly increased. Recently, another difference has been observed. The pH optimum of the directly acetylated enzyme is markedly higher than that of the original or the indirectly acetylated protein.

In view of the importance of the subject, considerable attention has been given to the degree of acetylation obtained with chymotrypsinogen. The degree of reaction was determined through the use of radioactive (C^{14}) acetyl. As might be expected, the quantity of acetyl introduced can vary widely, with corresponding variation in the properties of the acetylated product.

All this bears directly on the important question of whether the increased stability at high pH and the greater esterolytic activity of the indirectly acetylated protein is attributable to the acylation of some particular group or center, or simply to steric hindrance, which in this case would prevent the protein from rapidly changing its shape. The latter seems more probable, but the question is not settled, albeit very important to anyone hoping to find ways to "modify" an enzyme action.

This work is being discontinued because of the death of the collaborator.

D. Microbiology and Toxicology

1. Botrytis Bonification of Wine. Desirable flavors were developed in Thompson seedless grape juice and wine by submerged culture growth of Botrytis cinerea and by addition of Botrytis extract. Favorable comments were received when the Northern California Section of the Institute of Food Technologists was served a very inexpensive white wine that had been improved by addition of Botrytis extract. Bonification of Thompson seedless grape juice concentrate could open a considerable market for this commodity in Europe, which is presently short of inexpensive good-quality grapes. Thompson grape concentrate is used extensively in wine manufacture in areas outside of California where local grape production cannot meet the needs of the industry. Our results indicate the distinct possibility of Botrytis enzyme mixture being used to upgrade quality of white American wines. Cooperative work is being done with the wine industry to demonstrate the effects of Botrytis on larger fermentations than can be conveniently processed in our laboratory.

2. Mold Contamination of Fruit Products. The fungus Byssochlamys fulva resists heat treatments normally used in preservation of some fruit products, and spoilage outbreaks of this mold have been reported from Western Europe. Heat-resistant fungi, some tentatively identified as Byssochlamys,

have been found on grapes as they are brought from the vineyard to the crusher, but only at a very low level of contamination. Most appear to be removed with the pomace, since they are not commonly found in the juice. In thermal-death-time cans inoculated with large quantities of Byssochlamys, survival time exceeded 62, 25, and 10 minutes at temperatures of 190°, 194°, and 198° F., respectively. These studies were conducted in collaboration with the National Canners Association's Western Laboratory in Berkeley, California.

E. Technology--Process and Product Development

1. New Processes and Products. "Osmovac" dehydration of fruit is terminology we apply to a new process in which about 70% of the moisture in fresh fruit is removed by osmosis, and the remainder (down to less than 5%) is removed by vacuum dehydration. Small whole fruit or cut pieces of fruit are covered with dry sugar or a concentrated syrup. Water and other small molecules are drawn out of the fruit into the sugar or concentrated sugar solution. As dehydration proceeds, the sugar solution becomes more dilute and the solids in the fruit become more concentrated. Eventually the rate of moisture transfer by osmosis decreases, and the fruit is then finish-dried by other means. The second stage may also be carried out by conventional air drying. With vacuum dehydration, a crisp porous texture is retained making the product quite suitable for use as a confection or for incorporation with dry breakfast cereals. Products finish-dried at atmospheric pressures could be useful as ingredients for a large number of formulated products. Because high temperatures are not involved in this dehydration method, heat damage and loss of volatile flavors do not occur. Small amounts of the flavor components are lost into the syrup in the osmosis step. This byproduct syrup has a very dilute fruit flavor. Its use in canning fruits and in ice cream or frozen dessert formulas is feasible. A wide variety of fruits has been prepared in the laboratory by the Osmovac process. Color and flavor retention are exceptionally good. The sugar protects the color of cut fruits so that sulfur dioxide need not be added during dehydration; Osmovac dried fruits maintain their color in storage without aid of sulfur dioxide or other antioxidants. The Osmovac process has been applied with success to whole and sliced strawberries; pitted sour cherries; sliced bananas, apples, peaches, pears, pineapples, nectarines, plums, and papayas; and halved or sliced apricots. Enthusiastic response has been obtained for the quality of these products. Flavor stability during storage, engineering and economic considerations, and applications to other fruits are remaining tasks.

Aromagram flavor analysis to compare commercially freeze-dried strawberries with Osmovac strawberries showed a better retention of volatile components in the Osmovac product, confirming sensory evaluations comparing the products.

High-quality instant applesauce flakes which reconstitute in cold water were made from six varieties of apples with a modified atmospheric double-drum dryer. Vapors evolved during the drying were rapidly removed both from above and below the drums, and a jet of chilled air was directed at the product

film on the drums just before the films reached the doctor blades. High-sugar products are sticky at high temperature, thus the chilling was necessary so the film could be drawn from the drums by a variable-speed reel which metered the dry product from the drums and permitted control of final flake thickness. The product, being hygroscopic, was collected in a low-humidity chamber. Potential applications of this process, which can be used for other fruit purees as well, include production of instant fruit sauces, preserves, and apple butter, use in bakery mixes and confections, and compression of the dried products into flakes or disks suitable for packaging with dry breakfast cereals.

We are applying microwave heating in developing new processes and products. Energy transfer via microwaves provides rapid and uniform heating throughout the exposed material. Because the equipment is relatively expensive, we are combining microwave effects with conventional heat for blanching, drying, cooking, and warming. Large continuous microwave-generation equipment is now available commercially, and a new technique, microwave puffing, is available to produce quick-cooking products. Fruit and vegetable products are prepared by conventional dehydration techniques until the moisture content is reduced to 50% or lower. The products are then placed in a microwave processing chamber where a portion of the residual moisture is rapidly vaporized, which puffs the product. The product may then be dried to the desirable final moisture content by microwave drying or by other processes. Examples we have worked with are apple segments, potato slices, precooked beans, and precooked rice. In addition, we have used microwave heating to blanch large vegetables or large pieces of vegetables that are difficult to blanch by hot water or steam. Corn on the cob and Brussels sprouts have been blanched adequately with less total exposure to heat, and superior frozen products have been produced.

"Wurvac" is a term we have applied to a new process for stripping aromas from fruit and recovering them for reincorporation into concentrates. This method was found to be most suitable for obtaining heat-sensitive aromas, such as those from citrus and peaches, because it enables their recovery at low temperatures under vacuum. Loss of aroma components into the vacuum system, experienced in most existing methods, is prevented by absorbing the aroma in the sealant of a liquid-seal vacuum pump. Orange juice aroma solution contained aroma-contributing compounds not found in peel oil. Gas liquid chromatography was used to check the efficiency of the process and the quality of final products. Aroma solutions were evaluated by using them instead of fresh juice cut-back in citrus concentrates and for flavor potentiation of fruit drinks. Evaluations using both sensory tests and gas chromatography showed the aroma solutions to be of exceptionally high quality. Storage stability of aroma solutions obtained by Wurvac was found to be good even in cold storage above freezing. Much higher concentrations of fruit aroma can be achieved by Wurvac than by previous essence recovery systems.

Liquid carbon dioxide under pressure at room temperature has been found to be a selective solvent for fruit aromas. Preliminary experimentation was

conducted on recovery of apple aromas. Fruit constituents such as sugars, acids, inorganic salts, etc., are insoluble in liquid carbon dioxide and so are not removed. The selectivity of the solubility permits the extraction of aromatic materials in essentially pure form. Apples, pears, and other fruits have been processed in a continuous system at 25° C. and 65 atmospheres of pressure. The extracts obtained are comparable in flavor to the original, as evaluated by both sensory and gas chromatographic techniques.

Preliminary investigations on use of osmosis for concentrating liquid food products have been promising. Concentration at atmospheric pressure can be accomplished by the osmotic pressure differences between the low concentration fruit juice on one side of a dialysis membrane into a suitable concentrated solution on the other side. Water and very little else moves from the fruit juice into, typically, a concentrated solution of inorganic salt of some type.

Reverse osmosis is a process in which pressure considerably in excess of osmotic pressure is applied to the high-concentration solution so that the water moves through the dialysis membrane in the direction of the low-concentration solution. This pressure-induced reverse flow has been neglected in the past because very strong semi-permeable membranes were not available. Pressures up to 2500 lbs. per sq. in. are required for some products. We have prepared porous tubular membrane supports, following general methods developed for desalinization, and developed equipment for reverse osmosis concentration. Apple and orange juices have been concentrated to about 40% solids by pressures up to 2500 lbs. per sq. in. The rate of water removal decreases with increased concentration of soluble components. Some potential uses for reverse osmosis in agriculture are the concentration, with minimum flavor loss, of fruit juices and beverages, economic water recovery from brackish irrigation run-offs and processors' effluents, low-temperature concentration of liquid foods, concentration and salt removal from molasses and whey, concentration and acid removal from citrus juices and syrups, concentration of sugar beet thin juice, etc. Studies of these new processes will continue.

2. <u>New Dried Fruit Products</u>. Prunes and other dried fruits can be made more succulent and attractive by hydrating to very high moisture levels. A treatment with 10% sorbate solution preserved prunes at 55% moisture content. Diethyl pyrocarbonate at 0.05% concentration inhibited growth of molds and yeasts on prunes at 35% moisture. Combinations of reagents may be more effective than high concentrations of single reagents. Continued studies on mold-controlling agents for high-moisture dried fruit is of great interest to the industry.

Commercial interest has been developing in the non-setting raisin paste made by our heating process. Untreated ground raisins set to an intractable hard mass within a day or two after grinding, but a simple heat treatment after the raisins are ground imparts a soft pliable texture to the raisin paste, and the paste remains soft after 30 days' storage. In this form it is useful to the bakery trade in making cookies and pastries. Without the treatment, raisin paste could not be used as an ingredient for such products.

3. Grape Products. Low-alcohol and high-alcohol fermentations are being investigated to broaden wine product lines as a basis for increasing markets for grapes. Low-alcohol wines were prepared and treated to provide a beverage intermediate between grape juice and the usual table wines. High-alcohol fermentations, without sulfur dioxide, carried out on Thompson seedless, Sauvigon Blanc, and Semillon musts and concentrates yielded high-quality wines. Samples of these wines were presented to the Wine Institute Technical Advisory Committee for evaluation at a recent meeting. The high-alcohol fermentation produces wines that are easier to preserve and provides a dessert wine free from the heat-induced furfurals that arise from adjusting alcohol content upward with grape brandies. This non-fortified dessert wine is a completely new class of wine, but it does meet the standards of identity for the usual dessert wines.

Investigations are being conducted under contract at the University of California at Davis on new and improved methods for separating juice from grape pulp and seeds. A number of grape varieties were processed to show the effects on the skins of various heating times with fixed fermentation time. Heat was applied rapidly for 5, 10, 15, or 20 seconds. Taste scores on the different wines after 5 months of aging showed that heat-treated wines were superior or equal to unheated controls. For each variety, there was an optimum heat treatment. The amount of color extracted originally and retained during 3 months' aging was higher in samples that had been heated longer. Extracting color from skins of red grapes during fermentation is difficult to achieve without adversely affecting the flavor and red pigment stability. Very rapid heating for short periods appears to provide improved extraction and color stability compared with methods previously used.

A three-stage counter-current system was developed at Davis to recover sugar for fermentation from grape pomace. Earlier methods of washing the sugar from the pomace with water provided solutions that were extremely dilute and inefficient in later fermentation and recovery of alcohol. Allowing the fermentation to take place on diluted pomace led to difficult disposal treatments of the resultant still slops when the alcohol was recovered by fermentation and distillation. The new counter-current extraction method is more satisfactory in that adequate recovery of sugar from the pomace can be obtained in suitably concentrated solutions which can then be fermented to recover alcohol.

Investigations are conducted under contract at the New York Agricultural Experiment Station in Geneva on the chemistry of undesirable precipitates that form during the production and storage of wines. A thorough review covering the literature from America and Western Europe has been made of the use of protein tannin reactions for fining of fruit juices and wines. Preliminary experiments with model systems using tannin-gelatin and isinglass-tannin are being conducted to obtain data on the removal of tannins. The conditions for development of a tannin-protein haze in the solution is being studied and the research includes removal of haze by filtration as well as by fining.

4. Processing Quality of Northwest Fruits and Berries. Cooperative research with the Washington Agricultural Experiment Station continues. Seven varieties and 64 hybrid selections of strawberries, 7 varieties and 28 selections of raspberries, and 11 varieties of blueberries from the 1965 harvest were processed. Most of the selections were from the third year screening of 4,000 seedlings planted in 1963. Several promising selections from the 1960 plantings were re-examined. Of particular interest to plant breeders are selections that show superior tolerance to winter damage, which has been very harmful to berry growers in Washington and Oregon during the past several years. As a result of our examinations, more than half of the 64 strawberries and 28 raspberry hybrids evaluated have been discarded for lack of desired quality. The Hood variety, which was introduced by Oregon State University and the United States Department of Agriculture in Oregon last year, was found to be outstanding for preserves and freezing. Clone B-22, a virus-free clone of the Northwest strawberry, was judged equal to the current commercial Northwest variety for freezing.

Recipes for pectin-gel candies made with fresh-fruit concentrates have been distributed; they are creating some commercial interest in the Pacific Northwest.

The ranges in composition of Concord grape and grape juices were studied and some of the factors affecting composition determined. Maturity, seasonal weather variations, crop load, and soil fertility are the dominant production variables that affect composition. The composition attained by grapes appears to be more closely related to cumulative solar radiation than to cumulative heat units. Only in seasons of unusually low solar radiation do vines bearing crop loads exceeding 10 tons per acre fail to mature grapes to 16% total solids in central Washington. With similar crop loads, vines on more fertile soil product grapes of lower soluble solids and higher acid content than vines on less fertile soil. Seasons of low solar radiation result in grapes with higher acid content than in seasons of high solar radiation. Acid content more nearly reflects climate during the growing season than does soluble solids content because the acid content does not appear to be affected by crop size. The amounts of color, methyl anthranilate and tannin in grapes varied considerably from season to season, but production variables affecting these constituents were not apparent. Differences in composition of grapes affected flavor of juices mainly in sweetness and tartness. Adjustments of soluble solids and acids comparable to those used in preparing frozen concentrated sweetened grape juice evened out differences in original juice flavor.

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VEGETABLES

Eastern Utilization Research and Development Division, ARS

Problem. Vegetable growing occupies over 3 million acres, with a yearly farm value of a billion dollars. Utilization as processed rather than fresh vegetables provides a constant source of supply with less price fluctuation. Basic compositional research is needed to provide knowledge to constituents responsible for color, flavor and texture of vegetables and the changes these constituents undergo during processing, storage, and distribution. There is also need for application of these results to developmental research on new products and new and improved processing technology. Consumer preference is shifting to "convenience" foods. An even greater emphasis on quickly prepared foods is evident in modern military feeding where high bulk density, nonrefrigerated, and rapidly rehydrating products are of primary importance.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program employing chemists and chemical engineers in basic and applied research on vegetable processing and products. The Federal work is conducted at Wyndmoor, Pennsylvania. The scientific effort assigned to this area totals 3.6 scientist man-years and is currently engaged in research on technology-process and product development.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 48 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Technology - Process and Product Development.

1. Quick-cooking dehydrated vegetable pieces. Engineering research on explosive-puffing of vegetables has resulted in a process for making quick-cooking carrots, beets, sweet potatoes and rutabagas. As a result of modifications in the batch-puffing gun it has become possible to greatly reduce the cycle time. These modifications include changes in design of the gun and the use of superheated steam in the operation of the gun. A cost estimate based on the improved process indicates that explosive-puffed carrot dice made in California at a raw material cost of $25 per ton can be sold for 42¢ per pound. This is 13¢ per pound less than California Vegetable Concentrates is now asking for carrot pieces made by the explosive-puffing process. Research has continued on the compression of explosion-puffed carrot pieces before final drying to increase their density to that of conventionally air-dried pieces. The dense product retains the rapid rehydration characteristics of the uncompressed product.

2. Dehydrated mushroom product. A product of excellent flavor has been made by pulping fresh mushrooms, dehydrating the slurry and grinding the dry flakes into powder. Storage tests show that the drum-dried mushrooms can be stored

in air at room temperature satisfactorily for at least nine months. The development of a simple process for making a satisfactorily mushroom powder with the characteristic flavor of the cultivated material has attracted the attention of potential processors and will help the domestic producers who are suffering from importation of canned mushrooms from Taiwan. The mushroom powder can be used in soups and sauces, or directly as a condiment in foods without prior reconstitution, and could sell as low as $3.10 to $3.30 per pound of powder.

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For related publications of State Experiment Stations on Vegetable Utilization - Food see the Summary of Current Program and Preliminary Report of Progress from the Southern Utilization Research and Development Division, Area No. 7, or Western Utilization Research and Development Division, Area No. 9.

VEGETABLES

Southern Utilization Research and Development Division

Problem. Although extensive progress has been made in recent years in developing stable, attractive, and convenient to use vegetable products, new and improved processed products must be developed and means of stabilizing perishable vegetables provided to minimize the adverse effects of seasonable surpluses and unfavorable markets, and to provide an adequate supply of good food for a growing population. Product quality needs to be improved and processing cost reduced through the adaptation and application of the latest technological developments and nutritional findings. For example, a major problem of the cucumber industry, since most of the crop is brine-cured, is to improve the curing process so that no loss occurs in the value of the cucumber during the brine-curing and storage process and the cost of processing is reduced. New pure culture fermented products are needed to more fully utilize cucumbers and many other vegetables in attractive consumer items. As another example, a precooked, dehydrated, sweetpotato product has been developed which usually has good shelf life when sealed under an inert gas. It reconstitutes to a product having the characteristics of freshly cooked and pureed sweetpotatoes. Applied research on a pilot-plant scale is needed to obtain additional engineering and processing data applicable to commercial production of flakes from sweetpotatoes of different variety and environmental history. Basic research is needed to further improve quality and storageability of the product, and to provide the scientific basis for the development of a process for making excellent flakes from uncured, freshly dug sweetpotatoes. There is a continuing need in the use of vegetables for processing to investigate the characteristics of the raw material as these characteristics are affected by climate, soil, cultural practices, breeding, and the like. Celery, already an important flavoring ingredient, could become much more important if the factors and constituents responsible for the intensity, variableness, and stability of its flavor could be controlled in processing, and processed products of improved flavor and convenience could be developed. Many vegetables grown in the Southern Region differ in their chemical and physical characteristics from the same crops grown in the more temperate regions. Tomatoes are a good example in that they are frequently poorer in color, flavor and texture. Several vegetable crops, including sweetpotatoes, hot peppers, okra, and Southern peas, are grown almost exclusively in the Southern Region. More utilization research is needed to complement the Federal and State production research programs and to provide cooperation in the form of composition and processing studies. This kind of cooperation is needed to prevent the release of breeding selections which are entirely unsuited for processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, microbiologists, food technologists, and chemical

engineers engaged in both basic and applied utilization research studies on vegetables of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of vegetables, their products and byproducts, is conducted as a basis for efficient research in developing new and improved food products and processing technology. Research conducted at and in cooperation with the North Carolina Agricultural Experiment Station, Raleigh, North Carolina, is concerned with basic investigations of the chemistry and biochemistry of the carotenoid pigments in vegetables in relation to variety, maturity, and environmental factors, to facilitate the development of improved and more attractive processed products. Additional research on chemical composition and physical properties is being carried out under a grant at the Research Triangle Institute, Durham, North Carolina, on elucidation of the molecular structure and chemical characteristics of the pectinase inhibitor that occurs in sericea forage and other plant sources and has proven effective in preventing softening of cucumbers in brine curing.

Investigations of the effects of cucumber substrate, bacterial species, and other environmental factors on the flavor and aroma components of natural and pure culture fermented cucumber pickle products are carried out at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina, to provide the basis for producing pickle products of greater consumer acceptability. The North Carolina and Michigan Agricultural Experiment Stations, and the Pickle Packers International, Inc., cooperate in this research.

In the development of technology for new and improved processes and products, both basic and applied research is being carried out at New Orleans, Louisiana, to improve the stability of the flavor of precooked, dehydrated sweetpotato flakes packaged in air, and to improve the processability of uncured sweetpotatoes and their flake characteristics. These are two major problems still facing the new sweetpotato flake industry. Current research approaches involve the use of sweetpotatoes in combination with other foods to produce new products, the incorporation of nutrients, and investigation of constituent changes produced by the enzyme α-amylase. Pilot-plant investigations will also be conducted as a phase of this research. Cooperation is maintained with the Marketing Economics Division, ERS, for the market evaluation of improved flake products, and with the Louisiana Agricultural Experiment Station, the Louisiana Sweetpotato Association, the Louisiana Sweetpotato Commission, and various industrial concerns. Other research on process and product development is in progress at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina. Current emphasis is on investigations of methods for the controlled fermentation of cucumbers and other vegetables by application of pure culture techniques to fermentation practices in order to reduce processing costs and improve product characteristics. Limited cooperative work is conducted to evaluate new cucumber varieties (or selections) for processing into brine-cured and fresh-pack products. Cooperation is maintained with the North Carolina

Agricultural Experiment Station. The Michigan State University (Department of Microbiology) is also cooperating by providing technical assistance in the controlled fermentation studies. The Pickle Packers International, Inc., contributes support to the research and supplies raw material. The U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas, is conducting research directed toward developing new and improved processed products from southern grown vegetables other than sweetpotatoes and celery. The Texas Agricultural Experiment Station, the Crops Research Division, ARS, and industry associations provide raw materials of known history for this research. In progress at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, is research on the development of processed celery products of improved flavor and convenience.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 9.4 scientist man-years. Of this total, 2.2 is devoted to chemical composition and physical properties, 1.3 to flavor, and 5.9 to technology-process and product development. The domestic grant research involves an additional 0.6 man-years, on chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 48.0 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Investigations of the Chemistry and Biochemistry of the Carotenoid Pigments in Vegetables. In cooperative research with the North Carolina Agricultural Experiment Station on the chemistry and biochemistry of the carotenoid pigments in vegetables and fruits, the study of the carotene which stimulates photo-reduction of DPN has continued. This pigment has been reproducibly isolated from fresh spinach. Its spectrum does not show the fine structure characteristics of most carotenoids. Examination of a fraction of the pigment, believed to be the purest yet obtained, by infrared spectroscopy indicated that the compound is probably a poly isoprene with a carbonyl. The presence of a carbonyl is surprising since it was previously found that reduction with lithium aluminum hydride did not completely destroy activity. Raw and cooked carrots, sweetpotatoes, and tomatoes, all of which are high in carotenoids, have been examined with a spectrophotometer; in all cases, the carotenoid absorption spectra of the cooked slices shift toward lower wavelengths. This shift indicates a change in the physical state of the pigment. Impure chromoplast preparations undergo the same changes. Microscopic examination has indicated a loss of organization when a marked spectral shift occurs. This applies to chromoplast in the slice, isolated chromoplast, and suspended crystals. When the organization is thus disrupted by cooking, the carotene can be dissolved in other lipids. This change causes visual yellowing of the

product without the loss of pigment. It is probable that changes in the stability of the carotenes occur as their physical state changes. If this can be shown, spectral and microscopic methods may be useful for defining optimum processing conditions for obtaining more stable products, with respect to both flavor and color. Also, verification and exploitation of these preliminary observations should provide information which will guide processors in improving the color in processed products. (S3 5-28).

2. Identification and Characterization of Inhibitor of Enzyme that Softens Cucumbers. Under a grant with the Research Triangle Institute, the molecular structure and chemical characteristics of the pectinase inhibitor in sericea are being investigated. The first significant purification of the pectinase inhibitor beyond the caffeine method has been achieved by countercurrent distribution (CCD) systems. Several solvent systems were tested for their ability to fractionate the crude inhibitor material, but it soon became apparent that both phases of the CCD system would need to be highly polar. The results of preliminary tests with a neutral solvent system (2-propanol-water-sodium chloride) were promising enough to warrant a 200-tube CCD experiment, which was carried out on a 1.6 g. inhibitor sample. Two major fractions were separated; based on pectinase enzyme inhibition, the first fraction gave a very high purity with a freeze-dried yield of 0.265 g. The fourfold purified fraction was found to be less stable than the initial sample, a difference which suggested that a natural protecting agent (e.g. antioxidant) had been removed in purification. Since the inhibitor is a pro-anthocyanidin, the rates of pigment formation were given further study. Under controlled reactions, it was found that atmospheric oxygen and nitrogen had no effect, that benzoyl peroxide (radical initiator) increased color formation with destruction of the pigment, and that ferric chloride with HCl increased both the rate and final yield of the pigment. This basic information on the inhibitor reactions to form pigment should assist in a closer identity of the molecular structure with possible pathways to synthesis of the inhibitor substance. This is an important step in the commercial use of such material in the control of enzymatic softening of brined cucumbers. (S3 5-24(Gr)).

B. Flavor

1. Factors Affecting the Flavor and Aroma of Cucumbers and Fermented Cucumber Products. Basic studies of the flavor of cucumbers and fermented cucumber products are continuing in cooperation with the Pickle Packers International, Inc., and the North Carolina and Michigan Agricultural Experiment Stations. Direct headspace vapor analysis by gas-liquid chromatography (GLC) as a means of determining volatile components of fermented vegetables is being investigated. Data collected on 24 samples of fermented vegetables indicate that the "headspace" technique is reproducible, provided that factors influencing vapor pressure are standardized and that GLC profile data are related to a suitable internal standard (2-butanol in present case). Evaluation of the data indicated that the fermenting organism (of the three - Lactobacillus plantarum, Pediococcus cerevisiae,

Leuconostoc mesenteroides) can be predicted from GLC data on the basis of quantitative but not qualitative differences. The same volatile components seem to be present, even in acidified, nonfermented controls, but vary in concentration. Several methods are being used to identify these compounds. Findings thus far include: (1) acetaldehyde concentration is reduced by all three fermentations as compared to the acidified control, but most by L. plantarum; (2) a higher concentration of ethyl formate (tentative identification) occurred in the L. plantarum fermentation; (3) ethanol is much higher in the L. mesenteroides fermentation, as expected for a heterolactic organism; (4) several of the same compounds are present in similar amounts in both fermented and acidified products, and probably are not a function of the fermentation. Headspace vapor analysis is faster and gives better quantitative relationship of components than does the distillation procedure customarily used for qualitative identification of volatile components of fermented vegetables; however, a disadvantage is that only those compounds which are present in relatively higher concentration and have a sufficiently high vapor pressure can be measured. (S3 5-29).

C. Technology -- Process and Product Development

1. Investigations to Improve Quality and Lower Costs of Processed Cucumbers and Other Vegetable Products. Since there is an increasing need to ship cucumbers long distances before they are used for fresh-pack pickles and brine-stock, their quality must be preserved for several days. This problem is being investigated in a study of the pure culture fermentation of vegetable products, research that is also conducted in cooperation with the Pickle Packers International, Inc., and the Michigan and North Carolina Agricultural Experiment Stations. The increase in pectinolytic and cellulolytic enzyme activity on cucumbers during refrigerated storage was observed in earlier experiments. The hydrolytic enzymes were attributed mainly to increase in fungal growth on the cucumber. Bacteria are known to grow at refrigeration temperatures and produce pectinase. Two experiments using Model variety cucumbers were carried out under laboratory conditions during the 1965 growing season. These limited studies indicate that microbial deterioration is rapid (1 to 3 days) at 60° F. and 85° F. whereas the 40° and 50° F. lots showed little or no mold. Moreover it took 4 to 10 days for serious deterioration to occur at the lower temperatures. The degree of microbial activity is not always readily visible. Tests of pectinolytic activity and of cellulolytic activity indicated that of the growth media tested, the one showing cellulolytic activity appears to offer the most promise for indicating the degree of deterioration of the vegetable at a given holding temperature. This information has direct practical value for shippers, truckers, and processors. (S3 5-27).

Cooperative research with the Texas Agricultural Experiment Station to improve food products processed from southern-grown vegetables, including carrots and tomatoes, has continued. Completed storage studies have demonstrated that precooked dehydrated carrot flakes packaged in nitrogen

can be stored at 68° F. for as long as 24 months with little loss in quality. However, taste evaluations of air packs were discontinued at the end of three months because of poor flavor of the flakes. Unfortunately, the present yield by the double drum drying process appears to be too low to encourage commercialization of the process for making the carrot flakes.

Two practical pieces of information about tomatoes have resulted from recent research on improving processed products from Southern-grown vegetables. The effect of heat on the viscosity of tomato juice was analyzed for Chico, La Bonita, M-66, and Homestead varieties. When the juices were held at 190° F. for 2 hours, the viscosity of all except the last rapidly dropped, then remained constant; the viscosity of Homestead, very low initially, remained at the same level throughout the test. The concept that the viscosity of tomato juice will decrease rapidly when it is held for prolonged periods at a pasteurizing (canning) temperature is not new; however, these convincing specific data should encourage Texas canners to speed up their processing lines to achieve a quality pack of juice or puree. The second practical preliminary result is that tomatoes peeled in a $CaCl_2$ solution are as firm as tomatoes canned with a $CaCl_2$ tablet added to the can, but the $CaCl_2$ peeled tomatoes contain only about 1/3 as much calcium. Moreover, firming at the time of peeling may reduce loss in the processing line. To date, however, a satisfactory method has not been developed for recovery and reuse of the calcium chloride from contaminated blanch water. This project has now been discontinued, but leads on this phase of the research will be developed in a new project, also to be conducted in cooperation with the Texas Agricultural Experiment Station. (S3 5-22).

2. New and Improved Dehydrated Sweetpotato Products and Processes. The research to develop stable sweetpotato flakes from different varieties of sweetpotatoes has continued. The first phase concerns further study of the high temperature-tolerant α-amylase found in sweetpotatoes. In addition to achieving confirmation of previous results, recent research has shown that the enzyme increases during curing and storage. This is significant because it poses a continually changing seasonal problem in its control, as it converts starch rapidly when raw ground sweetpotatoes are cooked preparatory to making flakes. The addition of calcium salt enhances its activity. This enzyme can be activated in early season as well as late season roots by steam injection heating or indirect heating of sweetpotato puree, or by heating pieces (sliced or diced) of sweetpotato in water. Flakes produced by the latter method have an improved texture and more natural sweetpotato flavor when they are reconstituted. These observations now make it possible to prepare an acceptable flake product from the Goldrush variety under conditions of curing and storage studied to date.

The second part of this research consists of exploratory investigations of the preparation of new food products from sweetpotatoes. Pleasant tasting new drum-dried flake products have been prepared from sweetpotato puree

mixed with apple and peach purees. Also, pleasant tasting protein-enriched dehydrated products have been prepared from sweetpotato puree mixed with various types of peanut flours. Mixing a sweetpotato flour (prepared from flakes) with a low viscosity peanut butter has resulted in new products with consistencies varying from peanut butterlike to cheeselike. A study has also been initiated to determine factors affecting the bulk density of sweetpotato flakes. (S3 5-25).

3. Development of Processed Celery Products of Improved Flavor and Convenience. Significant progress has been made in research directed toward improving celery products. One problem had been that lack of uniformity in the moisture content of celery partially dried for explosion puffing prevents maximum rehydration of the dehydrated product. Pressing blanched, frozen, and thawed celery gave a much more uniform product for puffing than did pre-drying, and also considerably improved rehydration. When used in conjunction with other pre-drying treatments, pressing permitted the production of dehydrated celery that absorbed over 35 times its weight of cold water. The rehydrated products from such multiple treatments resembled freshly cooked celery in appearance and texture but they lacked flavor. A systematic study of several pre-drying treatments — including blanching, freezing and thawing, pressing, and leaching — was begun to clarify the rehydration process. Preliminary conclusions indicate that different pre-drying treatments may require different methods of rehydration to give best results.

Since it will be necessary to fortify the flavor of these products before they are marketable, it is encouraging that a practical method for producing essential celery oil for flavor fortification of dehydrated celery has been devised. It is based on steam distillation of raw celery material and rectification of the condensate. Adequate quantities of the oil can be obtained from leaves and trimmings normally wasted in harvesting celery. Preliminary studies of the composition of the essential oil obtained by rectification indicate that many more compounds, including additional phthalides, are present than previously found in solvent extracted oils. Several of the compounds isolated thus far that possess the characteristic celery odor have not yet been identified. Thus, the chemistry of celery flavor appears to be more complex than was first thought. It is desirable that the compounds in the oil be isolated and examined to determine their respective contributions to celery flavor. Work was also initiated on the development of a micro-method for determining the amount of oil present in fresh, raw celery, based on major flavor contributing phthalides. (S3 5-23(Rev.)).

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VEGETABLES

Western Utilization Research and Development Division, ARS

Problem. Vegetable crops, in general, are perishable and seasonal and thus are subject to supply and price fluctuations to the disadvantage of the agricultural economy. In order to expand markets and stabilize prices, new and improved processed products are needed that will be desirable to the domestic and foreign consumer from the standpoint of quality, convenience, stability, nutritive value, safety, and cost. The quality of processed vegetables and the economy of their processing have not improved rapidly enough to increase or even maintain the relative position of vegetables in the American diet, or to increase substantially their contribution to the export trade. The consumption of dry beans and certain other vegetables is limited by the fact that they cause flatulence.

New easy-to-prepare vegetable products are needed, particularly from such commodities as dry beans and peas, which now require hours to prepare. The severe heating required to sterilize low-acid foods, which include most vegetables, seriously impairs the quality of canned products. The stability of all kinds of processed vegetables needs to be improved so that quality and nutritive value will be better preserved during storage and distribution. The safety and effectiveness of new chemical additives, needed to improve the quality and stability of processed vegetables, must be established. Processing operations need to be modified to cope with special problems arising from the trend toward mechanical harvesting of many vegetables. Better methods of removing residues of agricultural chemicals from vegetables for processing are urgently needed, as are procedures for decontaminating vegetables exposed to radioactive fallout. Of vital importance is research to reduce the costs of processing in order that the farmer may receive a larger share of the consumer's dollar.

Applied research on these practical problems must be supported by a strong program of basic research on the chemical constituents of vegetables responsible for flavor, color, and texture; on the reactions these compounds undergo before, during, and after processing; on constituents having biological activity; on the microscopic structure of vegetables and vegetable products; and on the micro-organisms which cause spoilage or loss of quality in these products.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a broad program of basic research on vegetables and the application of science to new and improved products and processes is conducted at the Division headquarters at Albany, California, in field stations as Pasadena, California and Puyallup, Washington; by contracts and grants at Urbana, Illinois, East Lansing, Michigan, and Davis and Berkeley, California; and by grants under P.L. 480 in Finland, India, France, and Sweden. Fundamental studies

are conducted on the chemistry of vegetable flavors and vegetable pigments, the mechanism of heat resistance in bacterial spores, the composition of dry beans as related to cooking quality and flatulence-producing characteristics, the factors affecting deterioration of dehydrated vegetables, and the microbiology of raw vegetables for processing. Applied research is conducted to develop new and improved products including high-quality concentrated and dehydrated products and products of improved convenience; to improve processing methods, including freezing; to evaluate new processing varieties; and to develop methods for removing radioactive fallout.

The Federal program of research in this area totals 30.9 scientist man-years, including four scientists whose salaries are provided (two each) by the California Lima Bean Advisory Board operating under a State Marketing Order and the United States Brewers Association, and two summer student employees whose salaries are supplied by the National Frozen Food Packers Association; and four contracts and grants equivalent to approximately 2.3 scientist man-years per year. Of the total, 2.4 are assigned to investigations on chemical composition and physical properties; 8.0 on flavor; 4.9 on color, texture and other quality characteristics, and 9.2 on technology--process and product development. In addition, the Division sponsors three grants under Public Law 480 on basic research.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 48 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Composition of Dry Beans. The search for the fraction of dry beans that is responsible for flatulence was advanced by improvements in methods of gas collection and analysis. Breath analysis has been correlated with analysis of flatus, a correlation useful in experimental work. Breath hydrogen increases and decreases in a pattern identical with the fluctuations of flatus volume for 12 hours after a subject has eaten. In a cooperative study with the Department of Nutritional Sciences at the University of California at Berkeley, flatus and breath gas analyses were made on 12 human subjects to evaluate foods developed for the Gemini space flight program.

The new white Ventura variety of Lima bean was analyzed as to variation in its flatus-producing character during the growth and maturation of the seeds. The flatulence factor was present as much as three weeks before the beans reached a green-mature stage. Sprouted California small white beans produced the same degree of flatulence in human subjects as ungerminated beans. Lima beans of the Fordhook variety eaten in either the succulent green stage or the dry mature stage were relatively non flatulent.

The sugars, stachyose and raffinose, which were found in the flatulence-producing chemical fraction of dry beans, were fed in synthetic meals to six human subjects in cooperative research at the University of California. All six subjects showed a rise in breath hydrogen but no significant

increase in flatulence. These complex sugars are not readily metabolized by man, but they may serve as a substrate for intestinal microorganisms which produce one of the major flatus components, hydrogen.

Contract work at the University of Illinois on flatulence-producing properties of dry beans shows that anaerobic bacterial fermentation of some component(s) of beans is in part responsible for gas formation. Bean homogenates also have an inhibitory effect on intestinal carbonic anhydrase (an enzyme that facilitates transfer of carbon dioxide into the bloodstream), and thus they contribute to the accumulation of carbon dioxide in the intestine. Results of this research have not supported the idea that intestinal gas is formed by acidification of pancreatic bicarbonates. The work has further confirmed that stimulation of mechanical activity of the intestines is not a cause of flatulence.

An investigation of the proteins, amino acids, and biologically active components of dry beans is being conducted with P.L. 480 funds at Allahabad University in India. Nitrogenous constituents of defatted bean meal at various pH levels are being extracted with 8 different solvents at 3 different concentrations. The amounts and the nature of nitrogenous constituents extracted by different methods are under investigation. Protein fractions from 2 varieties of common beans were separated and purified and are being characterized.

B. Flavor

1. Vegetable Flavor Components. Aroma is an important attribute of most foods, as are taste, color, and texture. It has long been possible to measure chemically such taste-contributing constituents as sugars, acids, salts, and some bitter substances. It is also possible to measure color and texture fairly well by objective methods. However, until recent years little progress has been made in measuring the aroma-bearing constituents. Research that we have conducted has advanced the analytical techniques and is producing new knowledge which will be of value in the control of aroma of vegetable products and the development of new products of improved aroma.

Up to 150 parts per billion of hydrogen sulfide was found in the volatiles stripped in an hour from tomato products at 100° C. This is roughly 15 times the odor threshold of hydrogen sulfide in water. However, H_2S disappears in canned products by reaction with metals, and its overall importance to tomato products is probably much less than that of dimethyl sulfide, which does not disappear in the canned product.

Our research has revealed a substance not previously described in the literature but present in fresh tomatoes and also in considerably larger amounts in asparagus and cabbage. Preliminary studies suggest that the substance may be a short-chain molecule made up of amino acids and containing two or more glutamic acid building blocks.

Tomato powder dried by the foam-mat process is stable in nitrogen at room temperature for a year, but storage life is reduced at higher temperatures. Amino acids were determined and found to react during the storage of dried tomato powder. Such changes in amino acids may be connected with nonenzymatic browning and a consequent loss of flavor quality in tomato powder.

Investigations on organic components in vegetables and fodder plants is supported by a P.L. 480 grant to Nobel laureate A.I. Virtanen at the Biochemical Institute in Helsinki, Finland. Professor Virtanen has been studying the aliphatic sulfenic acids to which the lachrymatory substance of onion, propenyl sulfenic acid, belongs. His group has synthesized not only the propenyl sulfonic acid precursor, propenyl cysteine sulfoxide, but the corresponding lower homolog, S-vinyl cysteine sulfoxide, and the higher homolog, S-butenyl cysteine sulfoxide. Acids from these three compounds are formed from the sulfoxide under the influence of an enzyme preparation made from onions; they have similar lachrymatory effects. Newly discovered sulfur compounds have been isolated from onions and from the seeds of chives. A tripeptide consisting of glutamic acid plus 2 molecules of S-propenyl cysteine was identified. A study on decomposition or elimination of organic disulfide is in progress. The flavor substances of onion which cause off-flavor in milk when onions are fed to cows are disulfides.

The amino acid discovered by Dr. Virtanen to be a precursor of the lachrymatory principle in onions (propenyl cysteine sulfoxide) yielded a good clear magnetic resonance spectrum that established the molecular conformation indicating the trans nature of the double bond. This amino acid has been studied in cooperation with Mr. T. M. Lukes of California State Polytechnic College.

In studying these flavor compounds of onion and related compounds in other vegetables, mass spectrometry is providing a powerful tool for identification of individual components. However, in interpreting mass spectra, we are handicapped by a lack of knowledge of the ways in which molecules are fragmented in the mass spectrometer. To aid in this problem known compounds are synthesized so that their fragmentation patterns can provide insight and comparison with the patterns of unknown substances. When heavy hydrogen is incorporated in specific locations in synthetic compounds, the mass spectra produced yield information that is especially valuable in understanding the patterns of fragmentation.

New studies were initiated to develop an improved method for rapid evaluation of flavor strength of onions and onion products. A test more sensitive than the pyruvate method we developed earlier is desired by processors. Gas chromatographic analysis of onion vapors appears to be potentially useful for the purpose. Onion samples are crushed and the vapor above the sample injected into a capillary column gas chromatograph. Only a low concentration of volatiles appears immediately after crushing but in about 5 minutes peaks begin to appear in the gas chromatogram. The total area of all the peaks in the aromagram then increases markedly until an apparent

maximum is reached after 7 to 8 hours. From then on the peak area of the chromatogram decreases; this indicates a tailing off of aroma strength.

2. Flavor-Bearing Components of Hop Oil. In work supported financially by the U.S. Brewers Association, the volatile constituents of hop oil have been extensively studied using gas chromatographic separations. The compounds are identified by chemical and physical measurements of the isolated fractions. Well over 100 volatile components of hop oil have been isolated and identified, and we are now determining which of these are extracted from the hops and appear in hop beverages in their original form and which are extracted but altered in the brewing process. Hydrocarbons, which make up the major part of hop oil, are not extracted into the water phase and, therefore, probably contribute little if anything to the beverage aroma. The main volatile constituents extracted when hops are boiled in water are free organic acids. The main non-acid constituent appears to be humulene epoxide. Another important non-acid constituent identified by mass and infrared spectral evidence is humulenol, a rearranged product of humulene epoxide.

Determination of the odor threshold of hop constituents indicates that a large number of moderately odorous constituents contribute to the total hop aroma. In the making of beer when hops are boiled with the wort, the higher-boiling oxygenated constituents seem to transfer into the wort most efficiently, whereas the terpenoid hydrocarbons seem to be largely lost. Fermentation appears to change the chemical nature of many of the hop oil constituents that get into the wort, the principal change being the conversion of methyl esters to ethyl esters.

3. Sensory Analysis of Odor Qualities. The scientific study of olfaction has been hampered by much uncertainty about the specific property of a chemical compound that stimulates the sense of smell. The stereochemical theory of odor originally postulated seven odor standards based on descriptions most frequently found in chemical literature and the distinctive common molecular dimensions or reactivities consistent within each standard. Organoleptic judgments have been used to describe odors of chemicals quantitatively in terms of similarity to one of the the seven odor standards. Correlations have been drawn between odor similarity scores obtained by the panel of judges and the dimensional similarities exhibited by silhouette patterns of molecular models of the specific compounds. For each of the following odor classes--ethereal, camphoraceous, musky, floral, and minty--a highly significant linear correlation was observed. This provides strong experimental evidence that the phychophysical basis of odor is primarily molecular size and shape.

For further verification and more precise selection of the odor standards, an experimental procedure was developed using subjects with specific anosmia. People exhibiting specific anosmia cannot detect certain odors or cannot detect them at concentrations readily apparent to most people. It is postulated that a person exhibiting a specific anosmia would be lacking in

olfaction receptor sites having the capability of detecting molecules of a specific size and shape. Theoretically, the particular size and shape that he cannot detect would be considered a primary odor, approached by other compounds that are approximately the same size and shape. About 2% of the population have a specific anosmia for isobutyric acid (rancid, sweaty odor). These anosmic persons can detect isobutyric acid only in concentrations about 50 times higher than the threshold for normal observers. In comparisons using straight-chain acids with 1 to 10 carbon atoms in the molecule isobutyric-acid anosmics exhibit roughly the same degree of anosmia for the acids with 4 to 7 carbon atoms. About 30-fold concentration above normal is required for detection of these straight-chain acids. The ester, isobutyl isobutyrate, appears to be virtually unrelated because the threshold ratio for anosmics is only 2-fold. The highest threshold ratio so far observed was 95-fold for isovaleric acid. This suggests that isovaleric acid must closely approach the ideal molecular configuration for eliciting the "sweaty" primary odor. This basic research is providing a deeper understanding of the relationship of chemical compounds to specific odors and should be especially helpful in our research to produce products of improved flavor.

C. Color, Texture, and Other Quality Factors

1. Effects of Freezing Rate on Frozen Vegetables. If vegetables are frozen rapidly enough, for example with liquid nitrogen, solid carbon dioxide, or by other means, they can be thawed with very little, if any, cell wall breakage visible microscopically, and they have a texture more nearly resembling that of the fresh vegetables. Test panels were used to seek a correlation between human judgment of green bean texture and tissue damage that could be observed with a microscope. In order to study these factors in greater depth, new equipment for microscopic observation and for freezing under controlled conditions is being prepared. The National Association of Frozen Food Packers is providing salaries for two student subprofessional assistants to work during the summer season on this project.

Five varieties of green snap beans, including Blue Lake and four bush bean varieties, were used to study the effects of maturity and freezing rate on product quality. Three harvest dates and three freezing methods were used (frozen in the package, frozen loose on trays in an air blast, and frozen by immersion in liquid nitrogen). The greatest difference in quality of product was caused by the difference in freezing rate. The liquid nitrogen freezing gave the highest shear press values for all sieve sizes and for all varieties. Changes due to sieve size were not large when compared with changes due to freezing treatment. After the beans were cooked, those that had been frozen in liquid nitrogen were the firmest. Liquid nitrogen freezing tests with other vegetables and fruits showed that texture improvement was possible with asparagus and corn on the cob and that berries frozen in liquid nitrogen did not break down and lose their juice as rapidly after thawing as did berries frozen more slowly.

2. Histology of Dehydrated Vegetables. A common defect in dehydrated vegetables is their inability to rehydrate to their original moisture content, a defect that is particularly serious with onions, which are not blanched before dehydration and which may be merely rehydrated in cold water and eaten without cooking. Contract research on the effects of dehydration on reconstitution characteristics of vegetables is supported at the University of California at Davis. Freeze-dried onions reabsorb more water on reconstitution than do air-dried onions. In the case of freeze-drying, cellulosic crystallinity increased as drying progressed, but volume and texture changes were nil. In onions dried by other processes, not only did cellulose crystallinity increase, but the volume that could be regained on rehydration decreased and the toughness of rehydrated tissue increased.

3. Vegetable Pigments. The effect of dehydration and storage of dehydrated products on yellow pigments was investigated. Two varieties of parsley were selected to serve as models for pigment deterioration. Total beta-carotene content of the dried product that had not been blanched was quite stable; values were slightly higher than for blanched and dried material. Xanthophylls were similar. All-trans beta-carotene decreased after drying. Dried samples were stored for three months under nitrogen and under air at 22° and -18°C. A 10% to 15% loss of total carotene occurred in the unblanched sample during storage in air at 22° C.

D. Microbiology and Toxicology

1. Heat Resistance of Spores. The heat required to destroy bacterial spores and sterilize low-acid canned vegetables and other foods seriously degrades color, flavor, texture, and nutritional quality. In order to develop less-damaging processes, we are conducting a long-range basic study on the nature of heat resistance in bacterial spores. We have found that a previously unrecognized ion-exchange property of spores determines their heat resistance. The spores can be sensitized to heat by an acid treatment and this sensitivity persists temporarily when the product is returned to its original non-acid state. Consequently less heat is required to sterilize spores treated in this way. Spores of B. subtilis are resistant to heat when the ion exchange mechanism is loaded with calcium ions. Under acid conditions, hydrogen ions replace the calcium and the spores lose their resistance to heat. A reversible activation of spores of B. stearothermophilus was obtained by exposing the spores to a medium at pH 1.5, and then reversing the spores to dormancy by exposing them to an alkaline solution of calcium ions. A public-service patent on the method has been applied for.

Laboratory trials of reducing heat-processing severity have been made on a variety of commercial low-acid strained foods inoculated (10^8 spores per gram) with the flat sour organism, B. stearothermophilus. After addition to the food product the spores were sensitized to heat by acid treatment, then restored to their normal pH and heated to 240° F. Ratios of heating time required for a million-fold reduction of viable spores in the control-inoculated product to that in the acid-treated sensitized samples were

favorable. For strained carrots, a million-fold reduction of viable spores was achieved in one-eighth of the time required without the new treatment; in sweet potatoes, one-ninth; green beans, one-fourth; beef, one-fourth; beets, one-ninth; chicken, one-fifth; creamed corn, one-half to one-third; squash, one-eleventh; and creamed spinach, one-fourth. The acidification followed by neutralization provides a net addition of 0.2 to 1% sodium chloride to the product, depending upon which product is treated.

It is not contemplated or recommended that any reduction in severity of heating possible by this approach be extended beyond the usual process to prevent survival of the dangerous Clostridium botulinum. However, in commercial practice, heat severities of 2 to 10 times that required to control botulinum are used. Presumably several-fold reductions in heat severity for some products would be possible without subjecting products to danger of botulism.

Ultraviolet absorption spectra have been obtained on dry spores embedded in potassium bromide. These spectra, which are characteristic of calcium dipicolinate, provide evidence that at least part of the calcium and dipicolinic acid in spores are bound together in the form of a chelate. An improved spectrophotometric assay for dipicolinic acid has been developed. It represents a considerable gain in sensitivity and specificity that should be useful in many phases of research on heat-resistance of spores. Separation of spore populations in an aqueous density-gradient preparation has been made, and the fractions will now be studied for their dipicolinic acid contents and differences in heat-resistance.

Microincineration and electron microscopy applied to B. megaterium spores have revealed an organized mineral structure in the spore coat and have demonstrated the gross distribution of minerals throughout the spore. Electron microscopy also revealed the existence of a very thin membranous sac which apparently was released from B. macerans spores that had been dry ruptured. The sacs were relatively scarce in the preparations, and were difficult to detect because of their very low contrast. Nevertheless, they could be recognized with certainty by their distinct and uniform appearance. The membrane appears to be quite smooth without substructure at the highest magnification used and, in some instances, the membranous structure was seen protruding from the partially broken spore coat. The position and size of the structure suggest that it is either an inner layer of the coat or perhaps a separate membrane surrounding the spore cortex.

Basic research on factors that lead to bacterial sporulation are being investigated under a grant made to the University of Illinois at Urbana. Knowledge is being obtained on the biochemistry and physiology of Clostridium thermosaccharolyticum, an organism in which it is hard to induce sporulation. A procedure was developed that yields consistently 50-70% sporulation of two thermophilic anaerobic strains. Pea-extract media supplemented with manganese and iron were used, with close control of incubation temperature. Attempts to replace pea extract in the medium were not successful. Good progress

has been made on investigations of sporulation requirements and metabolism of these bacterial strains. The investigations also involve better methods of cleaning the spores and of determining their thermal characteristics.

Investigations of enzymes essential for spore germination are supported by a P.L. 480 grant to the National Institute of Agronomic Research in Paris. Alanine dehydrogenase and leucine dehydrogenase, which are involved in germination of B. subtilis spores, were isolated and characterized. Both have about the same molecular weight but different chemical reactions to very dilute mercuric ion concentrations. Morphological changes in spores during germination are being analyzed by electron microscopy.

2. Reducing Microbial Contamination of Processed Vegetables. Buyers of frozen foods for remanufacture have become more exacting in their specifications for levels of microbial contamination of products. We have been working cooperatively with the food preservation industry of the Pacific Northwest to obtain a clear understanding of factors that influence the microbial content of frozen vegetables. Surveys were made in plants freezing peas, beans, and cut corn. The neglect of good sanitary practices at any point in a processing line can undo the effectiveness of good practice at all other points. In one pea-freezing plant, for example, care was taken that peas passing through the blancher, quality grader, flumes, and inspection belts maintained plate counts well under the most exacting specification. In the freezing tunnel, however, which was not accessible to the cleanup crew, the bacterial count increased 10-fold between the last inspection belt and a spreader at the entrance to the freezing tunnel. This increase is enough to make the product unacceptable to buyers who specify microbial count.

In a number of investigations of commercial corn-freezing operations, high bacterial counts arose from washers, from conveyor belts which were inadequately cleaned or disinfected, from the tray spreader at the entrance of freezing tunnels, and generally from points where corn accumulated on guides, reels, or other equipment in the processing line. Accumulation of corn even at one point could contaminate the rest of the line and raise the count in the final product to more than a million viable organisms per gram. Use of in-plant chlorination, continuous rinsing of conveyor belts with chlorinated water, and split blanching operations with a second blanch as close as possible to the freezing operation, all lowered counts. Continuous attention to cleanliness of the line was found to be essential, and advice was given processors to enable them to bring microbial contamination into satisfactory control.

E. Technology--Process and Product Development

1. Tomato Products. Tomatoes are second only to potatoes as a processed vegetable. Although there is a wide diversity of tomato products, most of them are in the form of pastes, purées, or combinations of these concentrates with spices, sugar, etc., such as catsup and pizza sauce. The consistency of these products is an important quality factor.

We have been working cooperatively with an industry committee to develop an analytical method for testing raw material to determine its potential capacity to make products of a desirable consistency. Consistency of tomato products is largely determined by the amount and quality of pectic substances. Enzyme systems exist in tomatoes that very rapidly degrade pectic substances as soon as the tissue is disrupted. Processing methods have been developed to heat tomatoes very rapidly as they are crushed in order to reduce the degrading activity of pectic enzymes. We have discovered that by crushing tomatoes in the presence of acid, the enzymes are inhibited so that we can obtain tomato juice that has not been enzymatically degraded. This observation appears quite useful for obtaining a simple reproducible method for analyzing tomatoes for processing quality. Preliminary evaluations of the method we developed were made in 1965 and, because the results were promising, more extensive commercial testing of the analytical procedure will take place in 1966.

We are also applying this new method to a process for making tomato products of controlled consistency. By adjusting the level of acidity at the time the juice is extracted, we can make a high-consistency juice, a low-consistency juice, firm tomato-juice gels, or products like catsup or sauce with intermediate consistencies. Applications have been made for two public service patents to cover these processes.

We have prepared a series of tomato juice and concentrated tomato juice products with a starting range of pH from 1.0 to 9.0, by adjusting the pH at the time of juice extraction. Analyses of pectin fractions of these juices showed that at low extraction pH (1.0 to 2.0) the total pectin content was relatively high, and the pectin had a relatively high methoxyl content and a high molecular weight. At pH levels above 5.5, a high yield of pectin was also obtained but with a low methoxyl content. Tomato pastes were prepared from juices extracted at pH 1.5, 4.2, and 6.0 and dried on the foam-mat dryer. The drying characteristics of the sample having lowest pH were superior to the others, although the salt content was high as a result of the pH adjustment and subsequent neutralization. All the samples rehydrated readily to fluid products of excellent color and consistency. We hope to find specific processes to turn out tomato products to meet specific quality and consistency requirements.

A modified rotary steam-coil low-pressure evaporator has been designed and constructed to improve quality and reduce costs of concentrating food liquids such as tomato juice and fruit preserves. We call this the WURLing evaporator. High-quality pastes of 50% solids can be produced, although few other evaporators can produce 50% tomato paste without serious quality and efficiency loss from burning of tomato solids onto the heat-transfer surfaces. A rapidly whirling coil is completely submerged in the liquid under vacuum. Both submersion of the coil and its movement in the fluid help reduce fouling. By operating under vacuum, low-temperature steam can be used in the coil, and thus permit accurate temperature control and prevent the development of hot spots. Fouling is minimized, and the quality of the product is

preserved. One large installation of the WURLing evaporator has a capacity of 4-1/2 tons of high-density tomato paste her hour. Another application of the rotary coil vacuum evaporator is in making high-quality fruit preserves; a commercial installation has been made for this purpose. The WURLing evaporator has successfully produced high-quality preserves from strawberries, orange peels, sour red cherries, apricot purée, and pineapple chunks. A minimum of fruit breakage occurred because of the low-temperature boiling and the gentle agitation from the rotating heat-transfer surface. Configurations are being considered to design a commercial-scale vacuum jam maker that could operate continuously.

2. Frozen Vegetables. Experimental packs of vegetables frozen by immersion in liquid nitrogen and by immersion in refrigerated food-grade Freon 12 were prepared and evaluated. Green snap beans, Romano beans, cob corn, cauliflower, broccoli, Brussels sprouts, carrots, and hot-house rhubarb were frozen by immersion in liquid nitrogen. Green beans, Romano beans, and cob corn were superior in texture to their conventionally frozen controls. Broccoli does not appear to be adapted to immersion freezing in liquid nitrogen, since the florets are very brittle when frozen. Immersing the broccoli heads in water before liquid-nitrogen freezing (LNF) helped to keep the spear intact but did not eliminate the shattering of the head. Shear values of LNF beans of 5 varieties were always significantly higher than those of conventionally frozen beans.

Brussels sprouts, cauliflower, cob corn, carrots and hot-house rhubarb were also frozen by immersion in Freon 12. At a temperature of about -50° F., freezing in Freon was almost as rapid as in liquid nitrogen. There was less shattering with Freon immersion than with liquid-nitrogen immersion. Brussels sprouts, cauliflower, carrot strips, and hot-house rhubarb retained their textural properties better than samples that were conventionally frozen. Liquid nitrogen appears to have a good potential because textural qualities of such vegetables as cob corn and green beans very closely resemble the fresh, whereas conventionally frozen products lose much of their textural quality on freezing.

3. Dehydrated Vegetables. Factors that affect the rehydration of dehydrated vegetables are being investigated. Celery serves as a model. Air-dried celery rehydrates to only about 1/3 of its fresh weight, but when celery is dehydrated by alcohol extraction it absorbs more than its fresh content of water. Cooked samples that had been dehydrated by extraction with various alcohols had drained weights of from 125 to 156% of their fresh weight; cooked frozen celery had 90%. Although drying by alcohol extraction is not proposed as a practical method, its use in research is beginning to lay the basis for an understanding of rehydration phenomenon, and it may lead to processing methods that will improve a serious defect in dehydrated vegetables.

4. Dry Bean Products. Development of quick-cooking Lima beans is supported in part by the California Lima Bean Advisory Board. Improvements have been

made in the product previously described. Dry beans are rehydrated in a solution of four edible salts, with rehydration accelerated by fluctuating pressure. The new product, which could be marketed in dry form closely resembling unprocessed beans, can be prepared for table use in about 30 minutes by cooking in boiling water. The cooked beans have excellent appearance and flavor, and a prolonged soaking time is avoided while cooking time is reduced. The method has been applied successfully to prepare quick-cooking products from other types of dry beans. In cooperative research with commercial processors, large samples of quick-cooking beans have been prepared for evaluation in industry.

In storage tests of dry beans, Pinto and Sanilac varieties of low moisture (8%) possessed excellent cooking qualities after 4 years in storage at 70° and 90° F. High-moisture samples (15-16%) of large Limas, Pintos and Sanilacs showed small but significant increases in cooking time after 18 months at 40° and 55° F. Several-fold increases in cooking time were observed in similar samples stored at 70° F. Grade A beans are permitted to contain as much as 18% moisture. Recent results support the earlier investigation on beans which demonstrated a loss in cookability significant at temperatures as low as 40° F. and serious at 70° F. Dry beans for prolonged storage should have moisture contents of 11% or 12% or lower.

Investigations are being carried out by contract at Michigan State University in East Lansing to scale up our process for making precooked bean, pea, and lentil powders. We hope this will speed commercialization of the process. When beans were cooked in a retort at 250° F. instead of at 212°, it was possible to dry a puree made from them on a double-drum dryer without use of additives. Modifications were made in the dryer to increase its efficiency. Optimum dryer-operating conditions were established so that two pounds of product per square foot of drum surface could be dried per hour to a final moisture content of 5%.

5. Removal of Radioactivity from Vegetables by Processing. Investigations on the effect of commercial processing operations on removal of radioactive contamination are conducted by contract with the National Canners Association's Western Laboratory in Berkeley, California. This study includes possible removal methods for external contamination from fallout and for internal contamination from sources such as radiostrontium absorbed through the soil. It was found that more strontium accumulates in the interior of the potatoes than in the peel, so that peeling potatoes grown in contaminated soil would not effectively decontaminate them. On the other hand, normal processing operations for spinach, such as washing and blanching for canning or freezing, reduced external fallout contamination by 90%. Pea seeds, primarily because of the protection afforded by the pod, contained only traces of radioactivity when harvested one hour after exposure to simulated fallout. Strontium and calcium contents of the edible portions of peas, corn, apples, peaches, and pears grown in soil fortified with stable strontium were measured. The flesh of the three fruits was much lower in strontium than were the peels, pits, or cores. Pea seeds were lower in strontium

than the pods. Thus, at least in some fruit and vegetable crops grown in soil contaminated with radioactive fallout, much less radiostrontium would be translocated into those parts used for food than into those which are normally discarded.

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POTATOES

Eastern Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, has turned to and is becoming more and more dependent upon the development of new and improved processed products to maintain markets and avoid recurring economic disasters. Crop perishability, fluctuations in supply, and inelasticity of demand, result in wide price swings with even slight surpluses. Depressive lows are moderated by advance contracting by processors prior to harvest in producing areas having a substantial processing industry. However, in many processing areas, processing has not yet been developed and vulnerability still exists and is exaggerated by the growing competition of processed potato and other vegetable food products. If processing is to expand rapidly enough to offset progressive decline in fresh potato consumption, a continuing improvement in currently produced products and development of new products is clearly required.

Lack of adequate knowledge concerning the chemical constituents, physical properties, and enzyme systems in potatoes is limiting development of new and improved products and processing methods. Basic research on composition is needed to provide fundamental information on which an applied research program can be systematically and effectively built. Recently developed techniques make possible the isolation, characterization, and analysis of constituents responsible for flavor, color, odor, and texture of many processed food products which were not available to research in the past. Application of such techniques to potatoes and potato products should make possible the improvement of the quality of present products, both freshly processed and following storage, and provide a basis for technological and engineering studies in new product development.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied chemical and engineering research on studies related to processing. The work of the EURDD, involving the services of chemists, biochemists, food technologists and chemical engineers at Wyndmoor, Pennsylvania, and East Grand Forks, Minnesota, is conducted in cooperation with several Agricultural Experiment Stations which supply potatoes of known cultural history and with the marketing research facilities of the Department. The chemical research program includes: isolation and characterization of the amino acid-sugar intermediate compounds responsible for the browning of chips and French-fried potatoes during processing; studies on lipids, which are believed to play an important role in storage stability of processed potato products, particularly dehydrated products; isolation and characterization of the proteins, which are important from a nutritional aspect and from their possible involvement in textural and processing characteristics; elucidation of the causes of after-cooking discoloration and isolation and characterization of the pigment formed; methods of predicting textural characteristics of potatoes for French-fried potatoes. The Eastern Division's engineering and development research program seeks to improve the quality, nutritive value and storage stability of dehydrated potato products and to develop more convenient types of

dehydrated products, such as "Instantized" pieces that rehydrate and cook quickly. The Red River Potato Processing Laboratory, East Grand Forks, Minnesota, has been established to conduct investigations relating variety and other raw material characteristics to quality of established forms of processed potatoes. This Laboratory is operated jointly by the Red River Valley Potato Growers Association, University of Minnesota, North Dakota State University, and the Agricultural Research Service.

The Federal scientific effort devoted to this area at Wyndmoor and East Grand Forks, Minnesota, totals 12.7 scientist man-years. Of this number, research on chemical composition and physical properties amounts to 8.2, research on color, texture and other quality factors amounts to 2.3, and research on technology-process and product development comprises 2.2 scientist man-years.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 15 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties.

1. Basic studies on potato lipids. A method has been devised for determining the absolute amount of individual fatty acids isolated from potatoes. The new technique involves addition of a known quantity of a C-17 or a C-19 standard sample with the unknown, prior to saponification and extraction. Samples of potatoes harvested as the crop matures indicate that immature potatoes contain a considerable quantity of unsaturated acids and a new acid of about 24 carbons in the chain length.

Changes in the fatty acid content have been followed from tuber formation through maturation into storage for two varieties, Kennebec and Pontiac. Unlike the behavior of oilseeds, unsaturated fatty acids in potatoes appear to reach a minimum at the normal harvest time with little change in storage. It accordingly does not presently appear necessary to propose changes in harvest time in order to bring about any lowering in the unsaturated fatty acid level.

2. Basic studies on the proteins of potatoes. Earlier observation of quantitative, but not qualitative, differences in the protein composition of different varieties of potatoes were confirmed by the application of new techniques of separating the proteins. The water-soluble proteins have been separated into three fractions by gel-filtration. The first fraction appears to contain a small peptide or peptide complex. The second consists of at least seven components, possibly all glycoproteins. The third fraction contains 15-17 additional components. An effort will be made to isolate milligram quantities for further study. Most protein components of potatoes are indicated to have molecular weights below 100,000.

3. Basic studies on the after-cooking discoloration pigment. Study of the after-cooking discolorant was continued using an extract from a batch of potatoes of known high discoloration activity. Although the discolorant can be absorbed on activated charcoal from the deproteinized aqueous solution, desorption from the column has been incomplete. It is believed that the discolorant complex is degraded in all attempts at elution employed thus far.

Confirmation of the relationship reported earlier between tuber size and stem end blackening was obtained with three additional potato samples, two samples of Pennsylvania Katahdins and one sample of Red River Valley Pontiacs. Since no correlation has been found between blackening and specific gravity, the old idea that specific gravity is related to after-cooking discoloration can now be abandoned.

4. Basic studies on reducing sugars and enzyme activity of stored potatoes.

In research at the potato processing laboratory at East Grand Forks, Minnesota, two potato varieties (Kennebec and Pontiac) were harvested at two dates, stored at 40°F., reconditioned at 65°F. and analyzed for reducing sugars, invertase activity, invertase inhibitor, phosphatase, solids and phosphorylase. During the storage, reducing sugars increased sharply and high levels of basal and total invertase developed and reached maxima after 4-6 weeks of cold storage. On continued cold storage reducing sugars remained constant, basal invertase decreased to 0, total invertase decreased significantly and an excess of invertase inhibitor developed. When the stored potatoes were reconditioned at 65°F. the reducing sugars decreased markedly, basal invertase (if present) and total invertase decreased and a large excess of invertase inhibitor developed. These changes occurred mostly during the first two weeks. Since the inhibitor action increases with temperature, the relative behavior of invertase and its associated inhibitor at different temperatures provides an explanation of the mechanism whereby reducing sugars rise and fall inversely with the temperature of potato storage.

The synthesis of invertase by aerated potato disks was demonstrated. This result, apparently caused by wounding the potato, indicates the importance of careful handling of potatoes during harvest and storage.

Phosphoglucomutase, which plays an important role in carbohydrate transformations in potatoes, has been partially purified and characterized. This enzyme preparation has an activity four hundred times higher than that previously reported for potato phosphoglucomutase.

B. Color, Texture and Other Quality Factors.

1. Texture of French-fried potatoes. A study of the effect of raw stock and processing variables on the quality of French-fried potatoes has been studied. The variables under study include specific gravity, blanch time, fresh storage time, frozen storage time and reheating time. Difficulty in obtaining sufficiently close replication of shear has now been eliminated by selecting raw materials of comparable specific gravities. Shear values

within each fraction of a potato sample of comparable specific gravity can be duplicated closely. Cooling French-fried potatoes after reheating lowers the shear of the crust because of the redistribution of moisture from the interior to the surface. This leads to flabby pieces. A preliminary investigation of microwave oven blanching and reheating suggests that microwave heating may replace the standard blanching techniques but is not well adapted to heating frozen French-fried potatoes because a soft mushy product is invariably produced.

2. Pigments formed in potato frying. An ion-exchange procedure for isolating and identifying reaction products was employed in model experiments on the reaction of amino acids and sugar under conditions employed in potato chip frying. In studies of three sugars (glucose, fructose, sucrose) with several amino acids it has been found that the reaction rates with any one sugar vary widely with the amino acid involved and that the number of products obtained also varies. For example, 12 different compounds were formed when glucose was reacted with threonine, serine or asparagine. When arginine, beta-alanine or glutamic acid are reacted with glucose only a few compounds are produced. The concentration of some products reaches a maximum early in the heating period and then decreases. These studies on model systems have shown its possibilities as a procedure for elucidating the mechanism of browning during potato chip frying.

C. Technology - Process and Product Development.

1. Quick-cooking dehydrated potato products. In the new puffing gun which employs internally-introduced superheated steam in addition to external heat, potato pieces with an original moisture content of 20-25% moisture tend to clump in the gun. This difficulty has been overcome by precoating the equilibrated pieces with 0.75% by weight of potato solids of sodium silico aluminate. Charges of up to 20 pounds weight of potato dice so treated have been exploded in the pilot plant superheated steam gun without agglomeration. This additive is rated GRAS by Food and Drug Administration.

Conditions have been determined for the commercial production of quick-cooking dehydrated potato dice and slices by this process. A publication now in press gives details and a cost estimate showing that the greatly improved products can be made for only slightly more than conventionally dried pieces.

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POTATOES

Western Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, is becoming more and more dependent upon the development of new and improved processed products to maintain markets and to avoid recurring economic disasters. Crop perishability, supply fluctuations, and the inelasticity of demand result in wide swings in price with even slight surpluses. In producing areas having a substantial processing industry, growers can moderate depressive lows by contracting with processors prior to harvest. However, in many important potato growing areas where processing has not yet developed, growers are still vulnerable and the situation is exaggerated by the mounting competition from processed potato and other food products. A continuing improvement in processed potato products is clearly required if processing is to expand fast enough to offset the progressive decline in use of fresh potatoes.

To improve the quality of processed potatoes, ways must be found to eliminate the stale, earthy, rancid, green, and warmed-over flavors that are sometimes encountered in potato products, including dehydrated mashed potatoes, dehydrated diced potatoes, frozen french fries, frozen patties, and potato chips, and to retain the desirable natural flavor of freshly cooked potato. Research methods recently developed offer an opportunity to isolate and identify the constituents responsible for the natural flavors and the off-flavors, to develop rapid and sensitive analytical methods for their measurement, and to determine the raw material factors controlling formation of the various desirable and undesirable constituents in the fresh potato.

Further improvement in the texture of potato products is also needed. Fundamental histological and chemical investigations could reveal the causes of differences in the texture of potatoes, as a basis for developing improved processing methods.

Enzymes play a great part in the entire compositional pattern of the potato, not only the constituents responsible for flavor, off-flavor, color, and texture, but also those responsible for disorders such as black spot. Black spot causes severe losses, both to those who market potatoes fresh and to those who process potatoes, because trimming costs are sharply increased and yields reduced. Increased knowledge of enzymes is needed as a basis for solving the black spot and similar problems, for increasing use of potatoes by reducing costs, and for improving quality of both fresh and processed potatoes.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, basic and applied research on potato products is conducted at the Division headquarters at Albany, California, by a grant at Davis, California, and by

grant funds under P.L. 480 in Sweden. The chemistry of potato flavor and the compounds involved in deterioration of potato products are studied to provide a basis for new and improved potato processes and products. Histochemical studies are conducted to elucidate factors involved in the texture of potato products. Basic investigations on the enzyme systems involved in potato product discoloration and the mechanism of rancidity development are in progress.

The Federal program of research in this area totals 4.9 scientist man-years including the equivalent of 0.7 scientist man-years for a research grant. Of this number, 0.7 are assigned to chemical composition and physical properties; 1.2 to flavor; and 3.0 to technology--process and product development. In addition, the Division sponsors two research grants under P.L. 480.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 15 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Potato Components. Research has been initiated under a grant to the University of California at Davis to provide new basic information on lipid synthesis, lipid breakdown, and phospholipid transformation as they relate to rancidity in stored dehydrated vegetables. The lipids of vegetables are subject to oxidative degradation, a serious form of deterioration in potato products. This new project will provide insight into the mechanism of formation of fats in living vegetable tissues and, in the long run, it may provide us with ways to control fat composition in processed foods. Biochemical reactions stimulated when discs of potato tissue are aged in distilled water are under study. Under these conditions, linoleic acid, which is the major fatty acid of potato lipids, is formed from monounsaturated oleic acid.

These studies also utilize vegetables other than potatoes to determine the synthesis of lipid components. Either light or a strongly reducing substance stimulates the incorporation of acetate into the chloroplasts of butter lettuce. The light-induced stimulation incorporates the acetate into nonvolatile long-chain fatty acids, whereas the reducing substance converts the acetate into a lipid-like volatile substance that has not yet been identified. Acetate, which is a precursor in fatty acid biosynthesis, is present in spinach and lettuce chloroplasts. The origin of acetate for this purpose has not been discovered but some of the earlier postulations have been tested and found wanting. A heat-stable protein that is involved in the fatty acid biosynthesis, acyl carrier protein, had previously been isolated from microorganisms. In this work a protein that is different in molecular weight and thiol content has been isolated. It has the same function as the protein isolated from a bacterium.

Two P.L. 480 grants have been made to the Swedish Institute for Food Preservation in Gothenburg. Under one of these the role of metals in enzyme action is being investigated. The purpose is to elucidate the relation between chemical structure and catalytic activity of enzymes. Metal-requiring enzymes have been chosen as particularly suitable objects of investigation because the metal provides a natural label of the portion of the protein directly involved in the reaction. The molecular architecture, the amino acid composition, and the physical properties of five different enzymes are being studied. Laboratory procedures and methods of analysis have been advanced. For the enzyme 3-phosphoglycerate kinase at high concentrations of divalent magnesium ions, four binding sites exist. At low metal ion concentration there are only two. Carbonic anhydrase, alkaline phosphatase, laccase, and tyrosinase are the other enzymes being studied.

With the other grant, the relationship between oxygen pressure and the rate of oxidation of fats found in dehydrated vegetables is being studied by means of model systems. The autoxidation in such a system is related to that found in storage deterioration of dehydrated potatoes. Addition to the model system of certain pro-oxidative metal ions, divalent copper and manganese, reduced the rates at which oxygen was consumed at low oxygen pressure. The effect of certain antioxidants was prolonged if the oxygen pressure was low. The equipment modifications which have been made to improve the study of oxygen utilization at low oxygen pressure are considered a major advance and applicable to a wide field of research.

B. Flavor

1. Flavor of Potato Components. One of the common defects of dehydrated potatoes, particularly potato flour, granules, and flakes, is a rancid off-odor that results from the oxidation of the small amount of fat that is present. Positive prevention of rancidification has not been possible on a commercial scale through the use of antioxidants or nitrogen packing, although storage stability has been materially enhanced by such devices. The concentration of hexanal in the vapors over hot reconstituted potato granules has provided a good index of the amount of oxidized aroma. Non-enzymatic browning or scorching of dehydrated potatoes can occur rapidly in the final stages of dehydration if temperature is not carefully controlled. Browning occurs, but more slowly, during storage of the dry product. High storage temperature increases the rate of nonenzymatic browning. The concentration of certain branched-chain aldehydes in the vapors over hot reconstituted granules is a measure of the amount of scorching, although it has not been shown that these compounds themselves are responsible for the off-odor. Volatile compounds identified as emanating from both fresh and stale potato chips include acids, saturated and unsaturated aldehydes, ketones, and mercaptans, among others. Preliminary evidence indicates that carbonyls play important roles in the aroma of potato chips.

We have also studied the aroma of boiled potatoes in an attempt to discover something of the chemistry of cooked fresh potatoes. The sulfur-containing

volatiles from cooking potatoes were analyzed by gas chromatographic and chemical techniques. Methyl mercaptan and dimethyl disulfide were the major sulfur-containing compounds detected in the vapor. In smaller amounts were ethyl mercaptan, dimethyl sulfide, methyl ethyl disulfide, and methyl isopropyl disulfide. Several other compounds were detected in trace amounts. Hydrogen sulfide was produced in relatively large amounts and over extended periods during cooking of either fresh or dehydrated potatoes. Because these sulfur-containing compounds have such a low odor threshold, we believe they are important factors in potato flavor.

C. Color, Texture and Other Quality Factors

1. Color and Texture of Frozen French-Fried Potato Products. Nearly a billion pounds a year of frozen french-fried potatoes are produced. About 80% are used for restaurant and other institutional food services. Nevertheless, french-fried potatoes made from the frozen product do not meet specifications of certain large restaurant operations because color and textural quality is frequently not up to the standard achieved with fresh potatoes. We have developed a method for measuring objectively the color changes of fried potatoes, which will be useful in research aimed at improving the quality of frozen potatoes.

Microscopic studies have revealed that changes in texture occurring as a result of freezing, thawing and refrigerator storage are related to changes in the properties of the gelled starch. Starch retrogradation occurs, and consequently the water-holding capacity of the starch gel is altered. This influences interior mealiness but its relation to the crispness of the outer surface of french-fried potatoes requires further study.

D. Technology--Process and Product Development

1. Fat Uptake During Frying of Frozen and Thawed French-Fried Potatoes. Managers of many small drive-in restaurants have adopted the practice of storing frozen french-fries in the refrigerator where temperatures range from 35° to 50° F. We have investigated the quality changes that occur during a several-day holding period at 34°, 45°, and 55° F. An important observation was that the amount of fat absorbed by french-fries increases as a consequence of their being thawed and held in storage prior to finish-frying. In one experiment, potatoes that were finish-fried starting with the products frozen had a fat content of 8-9% as prepared for serving, those thawed and held at 35° F. had up to 13% and those that had been stored at 45° and 55° F. contained even more fat.

2. Improving the Stability of Potato Granules. A number of chemical additives are permitted in the manufacture of dehydrated potato granules. Common materials that aid stability are sulfur dioxide, butylated hydroxyanisole, butylated hydroxytoluene, and glycerol monostearate. High moisture levels inhibit oxidation but accelerate browning. Sugar or corn syrup solids added to potato granules of high moisture content protected the

granules to a significant degree against conditions that induce browning. Chelating agents, such as sodium acid pyrophosphate and ethylenediamine tetra-acetic acid, were applied to potato granules prior to dehydration and found to limit the evolution of hexanal from freshly reconstituted granules. The hexanal test is indicative of oxidative rancidity.

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III. MARKETING AND ECONOMIC RESEARCH

CITRUS AND SUBTROPICAL FRUIT

Market Quality Research Division, ARS

Problem. Research is needed to develop better objective indices for measurement of quality of citrus and other subtropical fruits. This would result in more meaningful grades and standards which could be better enforced. Instrumentation and automatic devices for quality sorting on a commercial basis might be possible. Decays and fruit soilage present serious problems in both domestic and export markets. Much research is needed to relate mechanical harvesting, handling practices, packaging, precooling and transit refrigeration to wastage, and to develop effective treatments for decay reduction. There is need for further research on controlled atmosphere storage for citrus and other subtropical fruits. Problems which are sometimes distinct and sometimes interrelated exist in each of the geographical areas. These often require biological research in the separate production areas for solution.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. Research is conducted in the producing areas of California, Florida and Texas. Market studies are made in Belle Mead, New Jersey and Chicago. P. L. 480 grants are operative for studies in India on identification and mode of infection of fungi causing postharvest rots of tropical fruits; in Spain on detection of additives in citrus juices; in Germany on the antimicrobial action of biphenyl; in Israel on maturation and ripening of avocados; and in India on metabolic changes during ripening of mangos. A contract study on citrus fruit quality as related to mechanical harvesting will cover one more harvest season at the Citrus Experiment Station, Lake Alfred, Florida.

Total federal scientist man-years devoted to this area is 12.4. Of this 1.5 is devoted to objective measurement of quality; 1.4 to quality maintenance during handling; 2.5 to quality maintenance during storage; 2.0 to quality maintenance during transportation (with emphasis on export); 2.0 to postharvest physiology; and 3.0 to postharvest disease control. P. L. 480 projects in this area involve $29,732 equivalent over a 5-year period in India; $56,163 equivalent over a 4-year period in Spain; $77,138 equivalent over a 5-year period in West Germany; $83,620 equivalent over a 5-year period in Israel; and $45,344 equivalent for a second 5-year project in India.

Projects terminated during this period included respiration and rind breakdown in citrus fruits (MQ 2-79) and precooling and transporting Florida citrus fruits and vegetables (MQ 2-53).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 7 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Non-Destructive Sorting of Citrus Fruits for Quality. Good color separations with the commercial light reflectance sorter were obtained on Temple oranges and limes. Tests using light transmittance for sorting Hamlin oranges according to degreening requirement show degreening time to be related to the initial chlorophyll level, supporting results of earlier work. Preliminary tests with the commercial light reflectance sorter showed similar results. Light transmittance chlorophyll readings for evaluation of internal quality of Hamlin and Valencia oranges and Marsh grapefruit gave average correlation figures of 0.3 to 0.4--too low to be of value in predicting quality.

Hamlin and Valencia oranges were measured with a new optics reflectance accessory to the spectrophotometer to determine the appropriate wavelengths to effect a separation based on surface color. For separating green, yellow-green to orange fruit, 760 nm as reference wavelength and 675 nm as measuring wavelength effectively separated this wide range in the fruit color. For separating yellow from orange fruit the best separation was obtained using 650 and 540 nm wavelengths. (MQ 3-77)

2. Aromatic Polynuclear Hydrocarbons in Citrus Fruits. A method was developed for the cleanup and screening of citrus extracts for residues of three hazardous polynuclear hydrocarbons. Over fifty paired samples of washed (non-waxed) and commercially waxed citrus fruit were screened for residues. No traces of the polynuclear hydrocarbons were detected. (MQ 3-46)

3. Seasonal Changes in Florida Persian Limes. Florida Persian limes picked 160 days after September bloom were larger in diameter but lower in total soluble solids and citric acid content than those picked at a similar interval from the February bloom; no difference was found in juice content of fruit from the September and February blooms. (MQ 3-53)

4. The Detection of Additives in Citrus Juices. Under this P. L. 480 project in Spain detailed analyses have been made of common additives such as sugars and citric acid. Trace components of the commercial materials are important chemical clues to their use as additives. Substantial data have been developed on the mineral constituents of pure orange juice and additional research on synthetic carotenoids shows that the method developed for their detection is effective. (E25-AMS-6k)

B. Quality maintenance in handling and packaging

1. Citrus Fruit Quality as Related to Mechanical Harvesting. A continuation of this contract research at the Florida Experiment Station through another harvest season largely confirms previous results. Both shaker and air blast methods of removal result in considerable fruit damage with an increase in postharvest decay. The results indicate possibilities for harvesting Hamlin oranges and Marsh grapefruit for the cannery but possibilities of harvest for fresh market appear remote. The only chemical under test that caused abscission injured the fruit and increased postharvest decay when the fruit was mechanically harvested. (MQ 2-65)

C. Quality maintenance in storage

1. Controlled Atmosphere Storage of Florida Citrus Fruits. Controlled atmospheres with numerous levels and combinations of carbon dioxide and oxygen showed no advantage over air for Temple oranges and tangelos stored at 33° F. Condition and flavor were good after 4 weeks in both CA and conventional storage. After 10 weeks, severe decay and chilling injury occurred in all lots. The flavor of Marsh grapefruit was retained in both CA and conventional storage at 50°. The smallest amount of decay developed in the 2.5% O_2-5% CO_2 atmosphere, but the most rind pitting developed in the atmospheres with 2.5% and 5% oxygen. Grapefruit waxed before storage developed more pitting than unwaxed fruit. (MQ 2-110)

2. Controlled Atmosphere Storage of California Oranges. Controlled atmosphere storage was evaluated for Valencia oranges during 4 months at 36° and 42° F. and Navel oranges during 4 months at 42°. Valencia oranges from CA were less acceptable than air-control fruit. Oranges from 1% oxygen were off-color and inedible. All Navel oranges except fruit from the 5% oxygen (flowing) and air-control treatments were inedible. Fruit from all static treatments showed some degree of off-flavor. (MQ 2-98)

3. Controlled Atmosphere Storage of Texas Grapefruit. Progressive infections of penicillium green mold, starting the seventh week, forced the termination of CA storage of Texas red grapefruit after 12 weeks. Rain which occurred on 20 of 27 days during December undoubtedly affected the keeping quality of this fruit which was harvested on December 27. Low CO_2 in storage atmospheres increased peel pitting which in turn provided entry points for green mold infections. Those lots stored with 2.5 to 10% O_2 and 2.5% CO_2 were in best condition after 12 weeks' storage. (MQ 2-98)

4. Controlled Atmosphere Storage of Florida Avocados, Mangos and Limes. At Miami after 30, 45 and 60 days in CA storage at 40° F., Lula avocados retained higher quality than comparable fruit stored in air. The most satisfactory atmospheres were 1% O_2-10% CO_2 and 3% O_2-15% CO_2. After 60 days' storage, most of the fruits showed darkening of the skin, although the flavor of the flesh was rated good. The best storage environment for Keitt mangos for 20

days was 55° in 5% O_2-5% CO_2. Diplodia stem-end decay limited the storage period. After 30 days in CA storage at 50° in 1% O_2-0% CO_2, unwaxed Persian limes developed less scald on the peel than the waxed limes. (MQ 2-110)

D. Quality maintenance during transportation

1. Thermal Conductivity in Florida Citrus Fruit. No appreciable differences were found in the thermal diffusivity of Marsh grapefruit during five different stages of ripeness. The coefficient of variation of 5.22 percent indicated the validity of the experimental procedure and suggests reliability in the experimental results. No significant correlations were found between the thermal properties of conductivity and diffusivity and the physical properties of rind thickness, moisture content, or size of grapefruit. (MQ 2-53)

2. Export Shipments of Florida Grapefruit. During April 1966, three export shipments of grapefruit were made from Wabasso, Florida, to LeHavre, France, primarily to compare shipping containers. In the first two test shipments, fruit in fiberboard cartons developed less decay than fruit in wirebound containers. No difference in total decay was observed in the third test. The fiberboard cartons shifted less on the pallets than the wirebound containers. The wirebound container is more flexible than the fiberboard carton, resulting in the frequent appearance of "jumble pack" of grapefruit and probably accounting for greater physical damage. Some of the commercial shipments showed soft and overripe grapefruit on arrival. The findings again emphasized the need of better fruit selection for export grapefruit. (MQ 2-74)

E. Postharvest physiology

1. Maturation and Ripening of Avocados. A first progress report on this P. L. 480 project in Israel indicates initiation of studies on growth-inhibiting and growth-promoting substances in avocado flesh. Identification of these materials is being attempted. Various known growth substances are being applied to avocado fruits and a device for quantitative measurement of flesh softening has been developed. (A10-MQ-2)

F. Postharvest disease control

1. Control of Decay of Florida Citrus Fruit. 2-(4-thiazolyl) benzimidazole (Thiabendazole), a new fungicide, was more effective in laboratory tests than sodium orthophenylphenate (SOPP) and 2-aminobutane in controlling decay of mid- and late-season oranges. In five controlled tests in commercial packing houses, 2-aminobutane was better than SOPP for reducing decay in citrus fruits.

Decay of Robinson tangerines was directly related to period of ethylene treatment (degreening). Excessive stem-end rot and anthracnose decay developed in fruit degreened for 45 hours or more. Fungicides tried were ineffective.

Postharvest Phomopsis side rot developed following grove inoculations made 4 months before harvest. (MQ 2-65)

2. Materials Affecting Germination and Growth of Decay Organisms. Germination of Diplodia natalensis spores in extracts of orange flavedo or albedo occurred over a pH range of 2.5 to 8. In .1 and .05 m. citrate buffer, germination was limited between pH 3-5 with a maximum at pH 4. Triton X-100, a wetting agent, did not inhibit germination, but when present with .05 m. buffer, germination was reduced and germ tubes were abnormal. (MQ 2-100)

3. Postharvest Diseases of Tropical Fruits. The survey of occurrence and identification of organisms causing postharvest decay in 6 tropical fruits is continuing under P. L. 480 grant in India. Post infection changes in sugar content of some fruits were studied by chromatographic analysis. Maximum, minimum and optimum temperatures and pH values for growth and sporulation of 3 common decay organisms were determined. Thirteen fungicides were tested for postharvest application. Of these, 6 were ineffective, others were effective against a few decay organisms and 3 chemicals checked the growth of all organisms. (A7-AMS-6)

4. Antimicrobial Action of Biphenyl. The literature review, which was the first phase of this P. L. 480 project in Germany, is completed and soon to be published. Research is underway on the influence of biphenyl and sodium orthophenylphenate on carbohydrate metabolism of Penicillium italicum and Trichoderma lignorum, both of which cause decay in citrus fruits. Inhibitory effects of biphenyl and SOPP were also related to pH of the growth medium. (E10-AMS-3)

5. Proteolytic Enzymes and Inhibitors in Decay Producing Fungi. Ten previously unreported host-pathogen combinations exhibiting protease action were discovered. Casein was found to be a better substrate, in most cases, for protease assay than either hemoglobin or alpha protein from soybean. It is now clear that proteases are produced during plant disease progression in a substantial number of cases. Some of these, for example Phomopsis stem end rot of orange, are important diseases on high-value crops. (MQ 2-97)

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DECIDUOUS FRUIT AND TREE NUTS

Market Quality Research Division, ARS

Problem. Deciduous fruits and tree nuts are subject to deterioration after harvest through normal metabolic processes and from decay organisms. In addition these products vary widely at harvest in the characters that determine market acceptance. Practical objective measurements of quality would greatly assist in standardization and grading procedures, and the development of instrumentation for this purpose increases the chance for automatic quality sorting on a commercial basis. Additional information on physical and chemical methods for decay reduction and on product quality as related to mechanical harvesting would be useful. Research is needed on storage environment as related to temperature, air movement, humidity, atmosphere modifications and fumigants. Research must be continued with transportation equipment and services as affecting ultimate quality of the product in the market. Dried fruits and tree nuts are subject to insect infestation while drying in the field, during storage while they await processing, in the processing plant, and in marketing channels until they reach the final consumer. Research is necessary to develop more effective measures for preventing insect infestation all along this line. Emphasis must be given to finding methods that will avoid both insect contamination and pesticide residues.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of basic and applied research involving horticulturists, plant physiologists, plant pathologists, and food technologists. The research includes definition, measurement, and maintenance of quality during the period between harvest and consumption. Locations include Beltsville, Md.; Wenatchee, Wash.; Fresno, Calif.; Raleigh, N. C.; Chicago, Ill.; and Belle Mead, N. J. Cooperative agreements and limited contributed funds are in effect with the California Strawberry Advisory Board. P.L. 480 supported research is underway in Finland on the effects of pesticide sprays on the storage life of certain fruits and in Italy on the principal rots of apples and pears.

A continuing program headquartered at Fresno, California, involves basic and applied research directed toward the prevention of insect infestation in dried fruits and tree nuts. The work is conducted in cooperation with California State and County agencies and several industry groups. Some of the latter provide limited funds through the Dried Fruit Association of California in support of the program. Much of the cross-commodity research at Savannah, Georgia, reported in Area 13, "Insect Control in Marketing Channels," is also applicable to the problems in dried fruits and tree nuts.

Federal effort in this program totals 19.4 scientist man-years divided as follows: Objective measurement of quality 2.7; quality maintenance in handling and packaging 2.8; quality maintenance in storage 2.7; quality maintenance during transportation 1.0; postharvest physiology 2.5; postharvest disease control 4.5; and prevention of insect infestation 3.2. Research under P.L. 480 includes a 3-year study in Italy for $18,357 equivalent; a 5-year project in Finland for $96,441 equivalent, involving the effects of pesticides on storage life and composition of fruits; and a 5-year study in Poland for $34,966 equivalent, on the ecology of mites attacking dried fruits and herbs.

Projects terminated during this period included: Control of pear scald (MQ 2-66), lenticel spot of Golden Delicious apples (MQ 2-72), gamma radiation on market life (MQ 2-82), quality measurement of apples (MQ 3-28), quality measurement of red tart cherries (MQ 3-27) and the P.L. 480 projects rots of apples and pears (E15-AMS-2a) and apple respiration in modified atmospheres (E29-AMS-1a).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 17 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Eastern Apples. Full spectral transmittance curves were obtained on intact Delicious apples (single and double red strains) grown in Maryland, and Starking Delicious grown in Washington State. Numerous wavelengths were correlated with destructive tests on individual fruit. ΔOD(600-640)nm correlated highest with soluble solids and Brix/acid ratio. (MQ 3-28)

2. Western Apples. Starking Delicious apples soften and have a progressive loss of chlorophyll with an increase in the number of days from bloom. Firmness and soluble solids are inversely corelated while titratable acidity and chlorophyll are directly correlated at each harvest date.

Golden Delicious follow the same trend as Starking Delicious except that Goldens soften more rapidly during the early storage period. Examinations after 3, 5, and 7 months' storage confirm that firmness, soluble solids, titratable acidity, and dessert quality of Golden Delicious are inversely related to the instrument measurement of internal chlorophyll at harvest time.

Alar (dimethylamino-succinamic acid) treated (preharvest) Golden Delicious were slightly preferred by a taste panel. Treated Golden and Starking Delicious were a little firmer than the controls after 7 months' storage. The treated Starking Delicious were less stale but more grainy in texture than the control fruit at the end of the storage season. (MQ 3-28)

3. Red Tart Cherries. Scald develops in bruised cherries in soak tanks with low oxygen concentration in the water. A tank aeration system was tested under controlled commercial conditions. A commercial aeration system proved an effective means of increasing oxygen level of water, thus controlling

cherry scald. Laboratory experiments with bruised cherries in water or in an N_2 atmosphere showed that 2 ppm of oxygen is the critical level below which scald develops.

Callose formation in bruised red tart cherries was demonstrated by means of aniline blue fluorescence method. Formation of callose is apparently related to the phenomenon known as firming which occurs when cherries are bruised and aged. (MQ 3-27)

4. Blueberries. Optical density differences between selected pairs of wavelengths in region 400-800 nm were explored for possible relationship with anthocyanin pigment content of individual blueberries. The highest correlation, 0.915, was found between ΔOD(700-800)nm and milligrams anthocyanin per berry. (Exploratory)

B. Quality maintenance in handling and packaging

1. Film Permeability for Apple Box Liners. Minimum and maximum carbon dioxide accumulations, calculated as arithmetic means on 27 lots of 5 test liners, containing 3 varieties of apples, during 180 days' storage were 4.1 and 6.6 percent, respectively. The oxygen atmospheres were 6.2 and 10.9. Final atmospheres were 4.4 percent carbon dioxide and 10.4 percent oxygen. A simple formula was developed to calculate a better index of liner performance than is possible with either a final or arithmetic-mean atmosphere. Analyses of 122 measurements of 5 film types showed that the ratio of carbon dioxide to oxygen increased 47 percent as temperatures decreased from 68° F. to 32° F.

Mechanically measured permeabilities of test films were compared with biological estimates computed by the RSAV method. When known variables were controlled, the results obtained by the two methods differed from each other over a range of 1.3 to 6.2 percent. The basic concepts of the RSAV formula were further confirmed. (MQ 2-63)

2. Blueberries. A survey of some 250 Highbush varieties and seedlings showed that acid content of fruit at the last identifiable stage of ripeness (purple at stem scar) varies from .5 to nearly 3.0 percent and soluble solids content from 6 to nearly 12 percent. Composition was to some extent correlated with the development of decay in such fruit. (MQ 2-94)

C. Quality maintenance in storage

1. Controlled Atmosphere Effects on Apples. Jonathan, Delicious, Golden Delicious, Rome and Stayman apples stored 4 and 6 months at 32° F. in 1% O_2 (zero CO_2) followed by 7 days at 70° in air were free of scald, Jonathan spot, shriveling and internal core or flesh browning. McIntosh apples stored at 38° in 1% O_2 had some skin and flesh browning similar to that found on fruit from zero O_2 atmospheres, indicating that 1% O_2 is insufficient for McIntosh.

McIntosh, Delicious, Rome and Stayman apples stored in air or polyethylene-lined boxes were moderately to severely scalded; Jonathans had severe Jonathan spot; and Golden Delicious stored in air were badly shriveled. Fruits stored in zero O_2 atmospheres developed variable amounts of skin and flesh browning and were off flavor. Carbon dioxide production in air after storage was lowest and acidity and firmness highest in fruit from the 1% O_2 atmospheres. (MQ 2-63)

2. Controlled Atmosphere Storage of Eastern Peaches and Nectarines. Firm ripe peaches stored 6 to 9 weeks in air at 32° F. failed to reach satisfactory eating ripeness when transferred to 65°. Those stored in 5% CO_2 and 21% O_2 were somewhat better than those from air. Those from the best atmospheres (1/4, 1 or 3% O_2 with 5% CO_2) were of borderline acceptability when ripened after 6 to 9 weeks of storage. Peaches stored in low-oxygen atmospheres with CO_2 respired more slowly during ripening and were softer, more acid, and had better flavor than those stored without CO_2. Late Le Grand nectarines stored in air at 32° F. failed to ripen satisfactorily after only 3 weeks' storage. Otherwise results with nectarines were similar to those obtained for peaches. (MQ 2-99)

3. Storage Life of Apples as Related to Rate of Cooling. Hydrocooled apples and those cooled in 3 and 7 days were of comparable quality at all examinations after storage. Apples cooled in 14 and 28 days were decidedly inferior to those cooled more rapidly as judged by flesh firmness and taste. Total solids and acids were about equal in all lots. The differences in dessert quality due to the different cooling rates became less pronounced with advancement of the storage season. A high percentage of the slowly cooled (14 and 28 days) Golden Delicious apples decayed during storage. Little decay occurred in Red Delicious fruit from any of the cooling rates. (MQ 2-127)

D. Quality maintenance during transportation

1. Air Shipment of California Strawberries. Domestic shipments--Summer shipments of California strawberries in jet cargo aircraft to eastern markets required an average of 17.8 hours from shipping point to wholesaler. Only 33 percent of the time was spent in the air, 21 percent on trucks, and 45 percent at airports. Ambient temperatures averaged 67° F.; precooled strawberries averaged 50°; and non-cooled berries averaged 65° during transit. Precooled fruit shipped on an open pallet averaged 54°, that on a pallet covered with a fiberboard sleeve averaged 51°, and that with a sleeve plus polyethylene liner, 45°. Differences in temperature due to type of pallet cover were smaller in non-cooled fruit, averaging 62° to 68°. Dry ice was effective in building up CO_2 atmospheres only when used with a polyethylene liner. Decay losses were smallest in precooled fruit, shipped with dry ice, on pallets covered with a polyethylene liner and a fiberboard sleeve. When fruit temperatures were kept below 40° F., the modified atmosphere produced by the dry ice was not needed. When temperatures were higher, the CO_2 given off by the dry ice partially compensated for the lack of refrigeration.

Spring shipments by air showed that low ambient temperatures (40° to 59° F.) lessened the effects of pallet covers, precooling, and dry ice on decay and fruit temperatures in transit. A fiberboard sleeve coated with polyethylene and wax was found to retain CO_2 moderately well, but not as well as the polyethylene liner. Tests made toward the end of the spring season when the weather was warmer showed that less decay occurred in berries shipped in the coated sleeves (plus dry ice) than in fruit shipped in the other types of pallet loads.

Export test--Berries shipped from Santa Maria, California, required 38 hours to reach Frankfurt, Germany. Ambient temperatures were mostly in the 65-70°F. range. Top layer fruit in the pallets had temperatures approximating ambients during most of the time in transit. Middle layer fruit temperatures remained in the mid 40's. Arrival condition of most of the fruit was good, but top-layer berries suffered considerable loss of quality and had more decay than fruit in the rest of the pallet load. Dry ice placed in the top layer had all sublimed before the end of the transit period. However, 11% CO_2 remained in pallet loads covered with a polyethylene lined sleeve when the shipment arrived in Frankfurt and 6% CO_2 remained in pallet loads covered with a poly-coated sleeve. (MQ 2-83)

E. Postharvest physiology

1. Scald Control for Apples and Pears. Various chemical and hot-water treatments applied to Stayman apples 1 or 2 days after harvest were evaluated for scald control following 5 or 6 months' storage at 32° F. Diphenylamine and ethoxyquin continued to give near perfect scald control but 30 or 60 second dips in 130° F. water also gave good protection. Scald control with hot-water dips was slightly better with warm (65°) fruit than with cool (40°) fruit and 30 seconds was safer than 60 seconds. A 30-second dip in 130° water increased core temperature about 2 degrees, and at 1/4-inch depth about 20 degrees. Heat-treated apples were hydrocooled to 35° without affecting scald control. A 30-second postharvest dip in 5,000 ppm Alar (dimethylamino-succinamic acid) gave little or no protection against scald. In one test, decay after storage averaged 9 to 14% in untreated lots and 1 to 2% in lots dipped in hot water before storage.

Scald inhibitors, DPA (diphenylamine) and ethoxyquin, when incorporated in wax, reduced scald intensity only slightly on Red Delicious apples, while plain wax intensified the scald. However, scald on Golden Delicious and Winesap apples was greatly reduced by the incorporation of either DPA or ethoxyquin in a wax coating. The best scald control of many treatments for Red Delicious apples was obtained by dipping the fruit in a water suspension of emulsified DPA and sodium-orthophenylphenate. Oiled paper wraps with ethoxyquin controlled storage scald of Golden Delicious apples completely while scald developed on 15 percent of the fruit in DPA wraps. Hot water at 125° F. for 3 minutes gave the best control of scald on Anjou pears. The next best treatment was the copper-oil wrap with added ethoxyquin. (MQ 2-91)

2. Effects of Pesticides on Storage Quality. One season's study under this P.L. 480 project in Finland was largely confined to the effects of postharvest applications of CIPC to ripening and composition of plums and tomatoes. Indicated effects of CIPC application were delayed coloring, starch hydrolysis, and ascorbic acid loss. The treatment did not cause any changes in pectin or dry weight. Much of the effort involved development of analytical methods. (E8-AMS-6)

F. Postharvest disease control

1. Stem End Decay in Pears. Penicillium expansum was not recovered from stems clipped from pear fruits in the orchard nor from fruit dumped at the warehouse. Pullularia pullulans, a fungus which produces an antibiotic, was recovered from the stems from both locations. There was less stem end decay in fruit dipped in Captan than in fruit treated with SOPP (sodium-o-phenylphenate) or with water at 125° F. for 3 minutes. Hot water at 130° F. for 3 minutes reduced germination of Penicillium spores by 95 percent. Four minutes' exposure at this temperature completely inhibited germination. (MQ 2-124)

2. California Grapes. Hydrocooled Emperor grapes stored at 32° F. for 10 weeks had better stem condition, color, and less shriveling than check lots that were precooled in air. Hydrocooling was done in field boxes (2 minutes) and the grapes were fumigated immediately afterwards (1.8% or 1.0% SO_2 for 1 or 2 minutes). SO_2 injury was less in hydrocooled lots than in the air-cooled lots. Ribier grapes reacted similarly, but differences between hydrocooled and check lots were smaller than in Emperors.

Thompson Seedless grapes from the early desert districts had brighter berries and greener, more turgid stems after 7 days at 40° F. and an additional 6 days at 70° when they had been hydrocooled than when precooled in air. Fruit with an initial temperature of 93° was hydrocooled to 52° in 2 minutes or to 40° in 5 minutes using 33° water. Grapes were cooled from 93° to 78° in 2 minutes with 70° water. The early grapes showed slight splitting of the epidermis when hydrocooled to 40° F. or 52° but no injury when hydrocooled to 78° in 70° water. (MQ 2-101)

3. Heat Treatment for Blueberries. Decay averaged 30% in seven lots of untreated blueberries from North Carolina or New Jersey after 2 days at 40° F. plus 4 days at 70°. A 2-minute dip in 125° water before storage reduced decay to 7%, and a 30-minute treatment in 110° air with 99% relative humidity reduced decay to 16%. Berries hydrocooled in clean water after a hot-water dip developed 17% decay, while hydrocooling in contaminated water increased decay to 80%. Berry temperatures rose to 113-123° during a 2-minute dip in 125° water. (MQ 2-104)

4. Decay Control for Strawberries. Exposure to 110° F. air of 90 or 98% relative humidity for 15 minutes and 1/2 hour, respectively, reduced decay in eastern strawberries significantly below that of the wet or dry checks during 4 days at 60° without injuring the fruit, or having any effect on

ripening or respiration of the berries. Exposure to 110° air of 50% relative humidity did not reduce decay. Dipping in 1.0 or 2.0% 2-aminobutane or exposing berries to the fumes of 0.1 or 0.2 gm/pt isomaltol also significantly reduced decay but often severely injured the caps of the berries. Dipping in 0.5% 2-aminobutane, or exposure to 0.05 gm/pt isomaltol reduced decay somewhat without injuring the fruit. (MQ 2-104)

Heat treatment of western strawberries at 111° F. for 1 hour in a water saturated atmosphere reduced decay caused by Botrytis cinerea and Rhizopus stolonifer by about 75%. Dessert quality was not impaired after simulated transit and marketing periods of 5 days at 37° and an additional 2 days at 59°.

Fresh strawberries held for 5 days at 37° F. in atmospheres with 0.5% or less oxygen had less decay than check lots, when examined immediately after storage or after an additional 2 days at 59° in air. Most of the decay was caused by Botrytis cinerea. Objectionable off-flavors developed in fruit held at oxygen concentrations of 0.25% or less. Development of off-flavors at low oxygen levels differed with the variety. (MQ 2-83)

5. Heat Treatment of Peaches. Peaches hydrocooled in water containing Monilinia or Rhizopus spores developed from 60 to 80% more decay than peaches hydrocooled in spore free water. Peaches heated in 130° F. water for 3 minutes were more susceptible to decay when hydrocooled in spore containing water than non-heated peaches or those heated in 120° or 125° water. All three temperatures reduced decay of inoculated peaches when hydrocooled in spore free water. Chlorine (100 ppm) in the hydrocooling water reduced contamination of peaches. Hot water treatment followed by hydrocooling with chlorine in the water effectively reduced decay. Hot water treatment of peaches, cooled for 24 hours at 32° F. before heating, effectively reduced decay. Water at 125° or 130° was more effective than 120° water. Internal temperatures of the precooled fruit after heat treatment were comparable to temperatures of peaches after hydrocooling. The 24-hour holding at 32° reduced Rhizopus but not Monilinia decay. (MQ 2-104)

6. Heat Treatment for Figs. Kadota figs were treated in water saturated air at 125° F. for 15, 30, or 45 minutes and stored for 5 days at 37° plus 3 days at 60°. Figs heated for 45 minutes averaged about 40% decay whereas the non-heated control averaged 85% decay. A taste panel could not detect consistent differences in flavor between the heated and non-heated figs. Black Mission figs heated 1 hour at 118° F. in water saturated air had no surface mold or decay while non-heated controls had 36% mold after 5 days at 37° plus 2 days at 60°. The taste panel could distinguish between heated and non-heated figs, but they did not find the flavor of the heated figs objectionable. (MQ 2-104)

7. Ozone Treatment of Peaches and Strawberries. Ozone applied at concentrations of 0.1 to 10 ppm for up to 6 days at 60° F. and 90% relative humidity did not reduce Rhizopus and brown rots of peaches. In concentrations above

0.5 ppm, ozone produced brown sunken areas at the stomata of peaches giving a pebbly effect on the surface.

Ozone at 0.5 ppm supplied by a commercial ozone generator capable of operating in high humidity did not improve appearance or reduce rot of strawberries stored at 35° F. and 90% RH. The caps of the berries in ozone shriveled and dried. Berries stored in ozone and tasted 3 to 6 hours after removal did not taste significantly different from those removed from air storage. (MQ 2-102)

8. Effects of Atmosphere Modification on Growth of Certain Fungi. The growth of four pathogens, Alternaria tenuis, Botrytis cinerea, Cladosporium herbarium, and Rhizopus stolonifer was reduced significantly with each decrease in oxygen concentration, when cultures were grown at 59° F. in atmospheres having 21, 1.0, 0.5, 0.25 or 0.0% oxygen. Sporulation was prevented at oxygen levels of 1.0% or less for B. cinerea, at 0.5% or less for R. stolonifer, but only at 0.0% for A. tenuis and C. herbarium. (MQ 2-112)

9. Radiation on Pathogenicity of Fungi. Fungicide resistance--Radiation induced sodium orthophenylphenate (SOPP) and sodium dehydroacetate (DHAS) resistant mutants of Penicillium expansum are genic in nature rather than due to cytoplasmic factors. Resistance to SOPP is controlled by at least 5 genes. Four chromosomes (linkage groups) are proposed for Penicillium expansum on the basis of crosses using known gene markers involved in the parasexual cycle. Cytological examinations also indicate that the nucleus in the haploid phase of this fungus consists of 4 chromosomes. All SOPP mutants were recessive while the DHAS mutants were dominant.

Host parasite relationship--Variations in availability of the amino acids methionine, arginine, leucine and histidine in the apple varieties Jonathan, Golden Delicious, McIntosh and Red Delicious influences their susceptibility to amino acid dependent mutants of P. expansum. Differences in vitamin content in these varieties apparently does not alter susceptibility. (MQ 2-96)

10. Control of P. expansum on Apples. Starking Delicious apples, inoculated with spores of Penicillium expansum were dipped in water (check), sodium-o-phenylphenate (SOPP), 5,000 ppm followed by a rinse; SOPP, 2,000 ppm without a rinse, 2-aminobutane (2AB), 5,000 ppm and thiabendazole (TBZ), 1,000 ppm. Decay after 7 days at 70° F. ranged from a high of 94.2% in the control to a low of 3.1% in the fruit treated with 2-aminobutane. SOPP treated fruit was only slightly better than the check. (MQ 2-125)

11. Aspergillus sp. on Raisins. Raisins collected from drying trays in a vineyard near Fresno, California, yielded fungi of the Aspergillus glaucus, A. flavus, and A. ochraceus groups. Subsequently, 66 samples from 16 locations in the San Joaquin Valley were cultured on agar media. Members of the A. glaucus group were identified from 46% of the samples and from 2 to 24% of the raisins in each sample were invaded. Only one sample of the 66 tested yielded A. flavus. Isolates of A. flavus grown on a water extract of raisins and incubated at 86° F. for 5 to 7 days produced moderately large amounts of aflatoxin B_1. (Exploratory)

12. Apple and Pear Rots. This P.L. 480 project in Italy has been completed. The research developed useful information on symptoms, rate of growth, and product susceptibility with 4 decay organisms common in apples and pears. The Bartlett pear and Red Delicious apple proved very susceptible to lenticel infections by Penicillium sp., whereas the Golden Delicious apple was practically immune to lenticel infections by either Penicillium or Gloeosporium. Of preharvest sprays tried, only Captan applied 3 times during the 5 weeks before harvest was effective in reducing postharvest decays. Postharvest chemical treatments were ineffective but hot water (3 minutes at 122° F.) substantially reduced decay caused by Gloeosporium. (E15-AMS-2)

G. Prevention of insect infestation

1. Improved Pesticidal Control Methods. Malathion dust and spray protective treatments were effective against insects during the first 8 months of a laboratory evaluation test planned to run a year. Different stages of the Indian-meal moth, saw-toothed grain beetle, and merchant beetle are introduced as test insects. After 8 months there are indications that mature larvae of the Indian-meal moth are surviving the treatment on prunes and continuing their life cycle. There are also signs that merchant beetles are developing from eggs introduced into figs with the lower treatment levels. (MQ 1-15)

Malathion dust and spray protective treatments on inshell almonds in small-bin intermediate-scale tests were effective for one year in keeping heavy introduced populations of the Indian-meal moth, saw-toothed grain beetle, and merchant beetle at low levels. Insect damage to the almonds was also held to a minimum. Application rates for malathion on the whole almonds ranged from 5 to 50 ppm. The highest residues found were 7 ppm on whole almonds, 2.2 ppm on the shelled nuts before processing, and 0.8 ppm on the processed nuts. (MQ 1-27, Rev.)

Studies in previous years have shown the effectiveness of a malathion treatment on trays on which grapes are dried for protecting the grapes and raisins against insect infestation during drying and subsequent storage. Studies on the 1965 crop to determine what factors affected pickup of malathion by the raisins indicated that dry ratio, sugar content, and average daily temperature were the most significant of 11 factors evaluated. The individual importance of each is not yet known. The field studies showed that a treatment on the trays of 100 mg. per sq. ft., rather than 200 mg. as used previously, would put an adequate protective deposit into the raisins and would not exceed the Food and Drug tolerance of 8 ppm. Malathion-treated trays will be used commercially for the first time on the 1966 crop. Indications are that this will be on an extensive scale and that industry is anxious to use this new research development. (MQ 1-34)

Dichlorvos applied in a wine cellar as a thermal aerosol once a week gave good control of Drosophila, and twice a week gave very good control. Daily application with a vapor generator gave excellent control. Analysis of air samples showed that workers could safely enter treated areas one hour after the application was completed. (MQ 1-34)

A laminate of kraft paper, 1-mil polyethylene, and 0.00035-in. foil resisted insect penetration for 6 months in a test of packaging materials for dried fruit. In another test a 3-mil polycarbonate film was effective for 5 months while a 1-mil film was slightly less effective. Other less effective materials were 1-mil polyethylene, and laminates of kraft paper with ½-mil polyurethane or 1-mil polyethylene, nylon, or polycarbonate. All common types of fig packages had some insect invasion within 1 month in the infestation room except a plastic cup with polyethylene cover. (MQ 1-22)

H. Objective Measurement and Evaluation of Quality.

1. Light-Transmittance Techniques in Apples. An extensive study was conducted with Red Delicious apples to determine the optimum wavelengths for light-transmittance measurement of apple quality. The absorption spectrum of more than 1,000 inteact apples was recorded at harvest time and after 5 months' storage. The wavelength range from 510 to 850 nm was recorded for each sample with the absorbance readings at every 10-nm interval punched on paper tape. Taste panel scores, soluble solids, and titratable acidity were determined upon removal from storage and this information was also punched on paper tape. The data are now being processed to determine the optimum transmittance measurement for each of the quality factors.

2. Sonic Resonance Techniques. Nametre Company of Edison, New Jersey, performed tests under contract to evaluate acoustic or sonic techniques for measuring textural properties of fruits and vegetables. Even though the majority of measurements were made on apples, an acoustic spectra has been successfully recorded for bananas, oranges, and tomatoes. Results on apples showed that it is possible to vibrate and resonate whole intact fruits and cylindrical sections of tissue taken from the fruit. Natural variability among apples and within an apple can be conveniently and accurately measured in terms of its modulus of elasticity and internal friction. The square of the resonance frequency of the whole apple multiplied by its mass has been designated by the contractor as an "acoustic maturity constant." It appears more likely, however, that this parameter will be more promising as a non-destructive measure of firmness within agricultural commodities.
(MQ 3-72(C))

Sonic resonant techniques were used to determine the dynamic elastic modulus and internal friction of apples, bananas, carrots, peaches, pears, sweet potatoes, and white potatoes. Sound energy radiated from a horn-type speaker driver was transmitted through air to cylindrical specimens of tissue suspended by two cotton threads. The frequency range from 100 to 10,000 cycles per second was scanned and the amplitude of vibration was recorded. The use of modulus of elasticity as a definitive, objective, rapid measure of firmness within agricultural commodities is being proposed. The higher the elastic modulus, the firmer the product; a decreasing elastic modulus indicates softening of the commodity. Representative values for elastic modulus, designated in lb. per in^2, for fully matured commodities are: carrots, 3910; sweet potatoes, 1900; Irish Cobbler potatoes, 1800; Red Delicious apples, 975; Red Haven peaches, 430; and Valery bananas, 150. Further evaluation of these techniques as related to textural measurement is planned.

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VEGETABLES

Market Quality Research Division, ARS

Problem. Most fresh vegetables are highly perishable. Research is needed on sources of inoculum and time of infection and physical and chemical methods for decay reduction. Basic studies are needed on cell metabolism as related to the causes and control of functional disorders and the nature of ripening and aging. Product quality as related to mechanical harvesting will need increasing study as will the effects of storage environment on keeping and eating quality. Safe and effective transportation can be accomplished only by continued research with transportation services, equipment, and methods as these affect ultimate quality of the product in the market. The increasing interest in liquid gases for transit refrigeration and atmosphere modification has posed a series of new problems relating to effects on the commodities from release of substantial amounts of nitrogen or carbon dioxide in the load compartments. Additional information is needed on objective indices for harvest maturity and quality factors as related to standardization and grading, and practical measurements for quality changes as the product moves through marketing channels.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of applied and basic research relating to quality measurement and protection of vegetables as they pass through the marketing channels. The work is conducted by horticulturists, plant pathologists, plant physiologists, and food technologists. Approximately 11.7 scientist man-years are devoted to research on vegetables.

Research is conducted at USDA laboratories in Beltsville, Md.; Fresno, Calif.; Miami, Fla.; Orlando, Fla.; Belle Mead, N. J.; Chicago, Ill.; and Harlingen, Texas, and at the North Carolina Agricultural Experiment Station, Raleigh, N. C.

Projects terminated during this period included gray mold of peppers (MQ 2-52), host-parasite physiology of market diseases (MQ 2-60), injury, decay and shrinkage of sweetpotatoes (MQ 2-73), gamma radiation on market life (MQ 2-82), chilling injury of eggplant (MQ 2-86), ripening of tomatoes (MQ 2-88), and antioxidants and metabolic inhibitors (MQ 2-61).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 23 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Sweetpotatoes. Correlation coefficients between carotene content and various color parameters (Hunter L, a_L, a_L/L, X/Y and $\cos\theta/L$) for either raw or canned roots were highly significant. Tested by the conventional $Z\text{-}X^2$ test, they were not significantly different from each other.

Percent reflectance at 480, 500, 520 and 540 nm was determined from spectrophotometric curves of 5 to 10 raw roots. Conversions to relative reflectance by wavelength were correlated with carotene content. The correlation between relative reflectance and carotene content was highly significant at all four wavelengths. The highest value ($r=0.858$) was obtained at 500 nm. (MQ 3-50)

B. Quality maintenance in handling and packaging

1. Lettuce. Weight loss during the holding of film-wrapped New Jersey lettuce was greatly influenced by humidity in the storage room air and by degree of perforation in film overwraps. Least moisture loss occurred in polystyrene wrapped lettuce at all humidities. Moisture loss and decay were inversely related. More decay in inoculated lettuce developed at 90 percent relative humidity than at the lower humidities. Generally, heads wrapped in the multiperforated films, polyethylene, polypropylene, polyvinyl chloride A and perforated cellophane had the least number of decayed heads. However, dehydration of outer leaves resulted in trimming losses in heads wrapped with these films at the lower humidities, especially in the more perforated ones. The most decay developed in lots overwrapped with the non-perforated polystyrene and the needle-perforated polyvinyl chloride B films. Usually more decay developed when polystyrene and polyvinyl chloride overwraps were heat-shrunk than when they were not heated. (MQ 2-80)

2. Rhubarb. Bunched, debladed rhubarb stalks stored in polyethylene-lined crates or in bunches in polyethylene remained acceptable at 32° F. and 85-95% relative humidity for 4 weeks plus one day at 70°; at 40° for 2 weeks plus 1 day at 70°; and at 50° for 1 week plus 1 day at 70°. Weight loss was less than 1% during 4 weeks at 32°. Abscission of petiole bases was found in stalks stored 2 weeks or longer at 32° or 40° in film liners or wraps and then held 1 day or longer at 70°. Dipping stalks in water at 125° F. for 2 minutes before cutting into one-inch pieces and packaging in perforated polyethylene film bags, reduced decay and extended shelf life an extra day at 70° beyond 1 day shelf life for non-treated pieces. (MQ 2-61)

C. Quality maintenance in storage

1. Sweetpotatoes. Detailed records were obtained in a new sweetpotato storage with trench heating and humidification and an overhead ventilation system. Temperatures and relative humidities were controlled within ±5° F.

and 10% of optimum, respectively, during October through April. Trenches 9 feet apart were better than those 18 feet apart. Air circulation was adequate when heat was supplied through the trenches by an oil-fired, forced-air furnace but fans were needed with electric strip heating. No chilling injury was detected and no chilling temperatures recorded even though outside air temperature dropped to 5° F. during a storm. Palletized field boxes of sweetpotatoes were cured about 7 days before moving to the storage room. No injury or decay resulted from carefully moving the pallet loads of sweetpotatoes with a fork lift.

Intercellular space of sweetpotatoes varied between 4 varieties at harvest but varied less than 1.5% within a variety from 3 harvest dates and 3 locations. Roots of two varieties of sweetpotatoes lost weight and volume continuously during curing at 85° F. and 85-90% RH. All roots continued to lose weight during storage at nearly the same rate. Those that had the long cures (14 to 35 days) were more pithy after storage than those cured for 3 or 7 days. (MQ 2-128)

2. Controlled Atmosphere Storage of Cauliflower. Exposure to high CO_2 atmospheres during storage or marketing causes discoloration and excessive softening of cauliflower (if it is cooked) soon after removal from the modified atmosphere. The physiological changes associated with this disorder appear to be reversible. Discoloration of California cauliflower, cooked immediately after removal from an atmosphere containing 15 percent CO_2 and 5 percent O_2 (7 days at 41° F.), was measured on a Hunter Color Difference Meter and had an average reflectance value of 37, whereas after 24 hours' exposure to air the reflectance value was 41. Shear-press resistance increased from about 40 lb. to 70 lb. during the same interval. The differences for both criteria are significant at the 99 percent probability level.

Texas cauliflower held in near-zero level of CO_2 in all reduced oxygen atmospheres had slightly better texture than those stored with 5 or 10% CO_2. An off-flavor was detected in cooked cauliflower previously held in either 5 or 10% carbon dioxide with 10% oxygen but not at 1 or 5% oxygen. (MQ 2-123)

3. Symptoms of Freezing Injury. External and internal watersoaking was present in about 30% of cucumbers held at 20° F. for 1 hour, and in 83% of those held 2 hours. Exposure for 1 hour or longer at 0° F. generally resulted in 100% external watersoaking. Watersoaking present immediately after freezing persisted throughout a 1-day holding period at 40° or 70°. Frozen cucumbers lost less than 1% moisture when held 1 day at 40° or 70° but shrivel was noted at both temperatures. Pitting developed on the surface of frozen cucumbers held at 70° for 1 day but not on those held at 40°.

Watersoaking was noted in 12% of freshly-harvested asparagus spears 20 minutes after being placed at 20° F. After 40 minutes, watersoaking was present in 62% of the spears. When asparagus was held at 0°, 72% of the spears were watersoaked after 20 minutes. The watersoaked appearance persisted after freezing. A 9% moisture loss, which occurred principally in watersoaked areas, caused severe shrivelling in frozen asparagus held 1 day at 70°.

After slight freezing watersoaking was observed in turnips in scattered, small, circular spots. After severe freezing the spots were coalesced into larger, solidly watersoaked areas most easily observed on the non-colored portion of the root. A "blistered" appearance, due to the formation of ice crystals between the skin and the flesh, was commonly noted on severely frozen turnips. When moderately or severely frozen, the turnips recovered much better at 40° than at 70°. (MQ 2-29)

D. Quality maintenance during transportation

1. Asparagus. Asparagus was exposed to variable and above-optimum temperatures (43° to 57° F.) during transit from California to New York when shipped in a nitrogen-refrigerated rail car. Decay at the butt end occurred in 70 to 90% of the spears in the warmest positions and in 10% of those in the coolest positions in the car. The spears grew 1 to 3 inches during transit at the warm locations. Spears in crates stacked directly under the gas discharge lines were injured by freezing.

Asparagus held at 60° F. respired about three times as fast in air as in 100% nitrogen. In the nitrogen atmosphere spears developed a "cooked" appearance, softened and had an offensive odor. Asparagus held in nitrogen at 33° for 9 days also developed a "cooked" appearance and a slight off-odor. Spears held in air remained in good condition for the entire period. Respiration rates of asparagus at 33° F. in atmospheres containing 1% and 1/4% oxygen were about 94% and 80%, respectively, of those in air. Injury was observed in spears from the 1/4% oxygen atmosphere but not in spears from 1% oxygen. Shear press readings indicated no difference in tenderness of asparagus held in nitrogen or in air at either 33° or 60° F. However, asparagus remained much more tender at 33° than at 60°.

In studies of the effect of high initial concentrations of CO_2 on asparagus quality, controlled leakage rates reduced the CO_2 concentration from an initial 20% by one-half every 7 hours (fast rate) or every 16 hours (slow rate). After 7 days at 36° or 41° F., decay was negligible in all lots. After an additional 2 days at 59° in air, about 19% of spears held in air only showed soft rot of the tips while only 5 to 10% of those receiving the initial CO_2 showed this decay. The benefits of the high initial CO_2 atmospheres were not evident in tests where the general decay level was low. Taste tests revealed no objectionable off-odors or off-flavors in the CO_2 treated spears. (MQ 2-84 and 2-71)

2. Lettuce. When liquid nitrogen was the only source of refrigeration, temperature variations within the load were excessive and maximum lettuce temperatures were high. More decay developed in lettuce in these trailers than in trailers that were mechanically refrigerated. However, russet spotting was reduced in the low oxygen atmospheres resulting from nitrogen refrigeration. Trailers having mechanical refrigeration supplemented with liquid nitrogen to modify the atmosphere gave a significant reduction in russet spotting with no increase in decay, when compared with conventional

mechanically-refrigerated trailers. About one-fourth of the conventional trailers had average load temperatures of 40° F. or higher during transit, even though all but one thermostat was set at 36° or lower. The average transit temperature of lettuce in all trailers of this type was 38°.

The general appearance (primarily color and freshness) of non-trimmed lettuce was not affected significantly by holding it one week at 36° or 41° F. in 1/2 to 8% oxygen. However lettuce held for one week at 50° in 1, 2, 5 or 8% O_2 and 3 or 4 additional days in air appeared significantly greener and fresher than that held in air throughout. The quality of lettuce held in air at 36° or 41° was equal to and often superior to that held in low O_2 at 50°. The rate of respiration (CO_2 production) of lettuce was reduced by about one-third to one-half in 1/2, 1, or 5% O_2 as compared with that in air.

Texas lettuce held 2 weeks in reduced oxygen levels with zero carbon dioxide showed no internal browning after 1 week in air. In contrast, heads from similar oxygen levels with either 5 or 10% carbon dioxide showed moderate to severe internal browning with those from the higher level completely worthless. Lettuce stored in air was equal in appearance to that held in zero carbon dioxide at all levels of reduced oxygen. (MQ 2-84)

3. Kale. Three samples of freshly cut kale were held 10 days at 36° F. under the following conditions: (1) in air; (2) in an atmosphere in which the oxygen was gradually depleted by respiration with a resultant build-up of carbon dioxide; and (3) in a similar atmosphere but with the carbon dioxide absorbed. The kale in condition (2) developed a bad odor by the seventh day at which time the atmosphere was 0.2% oxygen and 6.8% carbon dioxide. The off odor disappeared within 24 hours after the kale was placed in air. Kale held under conditions (1) or (3) retained normal odor and flavor. (MQ 2-71)

E. Postharvest physiology

1. Respiration of Minor Crop Vegetables. Topped radishes respire at a rate of 3-9 mg. CO_2/kg./hr. at 32° and 60-89 at 80°. Radishes with tops respire 2 to 3 times more rapidly. Green onions respire at a rate of 10-22 at 32° and 98-210 at 80°. Rhubarb stalks without leaves respire at a rate of 8-13 at 32° and 40-57 at 70°, and twice these rates with leaves attached. Yellow Straightneck summer squash respire at a rate of 12-13 mg. CO_2/kg./hr. at 32° and 85-97 at 70°. (No Line Project)

2. Russet Spotting of Lettuce. During 1965, six tests were conducted to determine whether a relationship exists between the incidence of russet spotting and mild field virus infections in lettuce. Lettuce with obvious mosaic symptoms had about half the incidence of russet spotting in the initial 5 tests as those with no visible symptoms cut from the same area of the field. In a sixth test, results were similar when lettuce was cut from the same area of a field. However, heads obtained from an apparently virus free area of the same field developed less russet spotting than those from the infected area which showed no symptoms. (Exploratory)

3. Translucent Scale of Onions. Preliminary results of tests involving approximately 1500 pounds of onions indicate that bruising by simulated commercial handling creates a translucent condition of the onion scale which might easily be confused with translucent scale described as due to physiological breakdown. It appears that there is a degree of recovery which is proportional to time after the bruising and temperature at which the onions are held. Onions held at room temperature and humidity recovered faster than those held at 40° and higher relative humidities. (MQ 2-111)

F. Postharvest disease control

1. Onions. The control of onion neck rot with heat treatments at harvest was better with fully mature onions than those less mature. However, results with either hot plate or flame treatments to the cut neck surfaces were erratic.

Preharvest treatments of the soil with 70 to 560 grams of hydrated lime per 5' by 20' plot failed to reduce decay of onions in storage. The higher concentrations of lime appeared to increase decay. Captan-50 wp and Difolatan 75% dusted on the freshly cut neck surfaces were the most effective treatments. Dusts of 6% Botran, Dithane 22, Calcium Chloride and Daconil 2787 were less effective. Decay after 4 to 5 months in common storage was 79% in the controls and 8.3 and 3.3% in the best treatments. Muck soil mixed with inoculum was applied to the cut surfaces following treatment in all lots. (MQ 2-95)

2. Soft Rot in Bell Peppers. Harvested peppers from controlled nitrogen fertilizer plots were inoculated with soft rot bacteria to determine any difference in their susceptibility to infection. Also, some inoculated pods were treated with hot water (128° for 1.5 minutes) to determine any difference in reduction of infection. Pods from the high nitrogen plots showed nearly the same percentage of positive infections (80%) as pods from the low nitrogen plots (70%). The hot water treatment was most effective with pods from the lowest nitrogen plots where the reduction in infection was 50%. (Exploratory)

3. Sweetpotatoes. The death of sweetpotato tissue when immersed in an acetone-insoluble fraction of the juice expressed from Rhizopus-rotted sweetpotato, can be prevented by heating the fraction at 131° F. for 10 minutes. Macerating and toxic activities could not be separated by dilution, by varying the pH from 3.0 to 8.0, or by dialysis of the fraction against distilled water or buffer. This evidence suggests that the toxic principle is protein in nature. Death of the sweetpotato tissue was retarded and maceration was prevented by the addition of 0.5 M KNO_3 to the toxic fraction. (Exploratory)

4. Cantaloups. Immersion of Texas cantaloups for 30 seconds in 135° F. water consistently reduced, and often eliminated, visible mycelial growths on stem scars and rind for 6 days at 60°. Increasing the temperature of the water to either 140 or 145° provided slightly better protection against mold and a marked reduction in bacterial infection of stem scars. Protection against mold and bacterial growths diminished with additional holding over 6 days.

Sodium o-phenylphenate (SOPP) at 0.1 to 0.3% was tested in hot water. Injury, evidenced by browning of sutures and stem scars, resulted with the use of 0.3% SOPP heated to 145° with the 30-second immersion. The results to date do not justify the added expense of including SOPP in the hot water treatment. Treating melons in 135° F. water for 30 seconds increased the pulp temperatures at the 1/4 and 1/2-inch depth 18 and 8.5 degrees, respectively, but the melons cooled to pretreatment temperature (87°) within 15 minutes after treatment. (Exploratory)

A stem-end decay of western cantaloups by Geotrichum candidum was identified on the New York market. Pathogenicity tests indicated the fungus was a weak parasite that developed best in ripened melons at relatively high temperatures. (MQ 2-64)

5. Effects of Chlorine on a Vegetable Decay Organism. Surfactants were found specific in their effect on fungicidal activity of calcium hypochlorite solutions on Alternaria tenuis spores. Certain surfactants increased fungicidal activity at pH 7 and others at pH 8. Depending on the surfactant, raising the surfactant concentration increases or decreases fungicidal activity.

Commercial field washing of mature-green harvested tomatoes in water containing no disinfectants increased the incidence of bacterial soft rot and bacterial necrosis. Holding the field-washed tomatoes at chilling temperatures greatly increased the incidence of both. Commercial field washing and hydrocooling celery with no disinfectants in the wash or precooler resulted in increased bacterial soft rot. Commercial packinghouse washing of carrots without disinfectants in the water resulted in increased bacterial soft rot. (MQ 2-116)

6. Effects of Ozone on Lettuce and Tomatoes. As little as 0.05 ppm of ozone injured the outer leaves of head lettuce held for 8 days at 36° F. and 90% relative humidity. A cooperative study in commercial tomato ripening rooms showed that ozone at 0.05 ppm had no effect on decay of tomatoes ripened at 65° F. and 80-90% RH. (MQ 2-102)

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POTATOES

Market Quality Research Division, ARS

Problem. The increased demand for potatoes to be used for chips, frozen french fries and other processed forms has created special problems of preventing undesirable chemical changes due to low temperatures during storage and transport. The use of higher temperatures has brought on additional problems of moisture loss and of bacterial and fungal decay. Higher temperature storage also calls for control of sprouting, with increased emphasis on sprout inhibitors. Objective indices are needed to identify quality factors that are important for specific product usage and relate measurable characters of the raw product to quality of the processed product. Also needed are instruments for non-destructive detection and rejection of potatoes with internal disorders during grading.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving horticulturists, plant pathologists and plant physiologists engaged in applied and basic research. The work at East Grand Forks, Minnesota, is conducted in cooperation with the Minnesota and North Dakota Agricultural Experiment Stations and the Red River Valley Potato Growers Association. The work at Presque Isle, Maine, is in cooperation with the Maine Agricultural Experiment Station. Research on transportation of early potatoes for chips is conducted by the Fresno, California, station. The studies at Beltsville involve quality evaluation, sprout inhibitors and basic research. Studies on market diseases are conducted at Chicago and Belle Mead, New Jersey.

The Federal effort devoted to research in this area totals 4.7 scientist man-years. Of this number 0.3 is devoted to quality evaluation; 0.5 to quality maintenance in handling and packaging; 1.5 to quality maintenance in storage; 0.2 to quality maintenance during transportation; 0.2 to postharvest physiology; and 2.0 to postharvest disease control.

One project was terminated during this period: Loading methods and protective services for Maine potatoes. (MQ 2-42).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 8 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Color Measurement in Potato Chips. Potato chips ranging in color from very light to very dark were measured with 6 different instruments. The same samples were also rated visually using the National Potato Chip Institute standards as a guide. The data suggest that potato chip color can be satisfactorily measured with several instruments and in a variety of forms (whole chips, ground, or pressed cake). Correlation coefficients between visual judgment and spectral reflectance at 546 nm, Hunter Rd or L, and tristimulus values X, Y, and Z were all highly significant and appear promising as a basis for purchase of potatoes for chipping. (Exploratory)

2. Moisture measurement of potatoes. Preliminary work on the measurement of moisture content of potato slices indicates promise. The absorption difference, Δ O D (865 - 815 nm), was found to be inversely correlated with moisture content for potato slices having 70 to 80 percent moisture.

The large standard error of ± 1.0 percent was caused by variations in the light-scattering properties of the samples. The light-scattering properties are also a function of moisture content, and a study of the light scattering indicates the possibility of a more precise moisture determination by measuring both absorption and scattering power. This will be studied further.

B. Quality maintenance in handling and packaging

1. Stone Separation and Tuber Bruising. Exposure of tubers to water during flume handling had no detrimental effect on the quality for seed. Quality studies were made after transit, storage and in field trials.

A study of the relation of soil temperature, air temperature, and tuber temperature to the resistance of tubers to bruising indicates that soil temperature during harvest may play a more important role in bruising than air temperature. Subjecting tubers to a temperature different from that in storage shifted resistance to bruising-- increased resistance if moved to warmer air; decreased resistance to bruising if moved to air cooler than the tuber. Gradual warming over a 3- to 4-week period increased bruise resistance more than rapid warming. (MQ 2-93)

C. Quality maintenance in storage

1. Storage Temperature on Processing Quality. Decay in potatoes stored 2½ months at 55° F. for chip manufacture ranged from 3 percent with an airflow rate of 2 cfm/cwt. to 27 percent with gravity airflow (near zero). Internal black spot, however, was nearly four times as extensive at the 2 cfm/cwt. rate as with gravity airflow. Decay and internal black spot at 0.4 cfm/cwt. were intermediate. (MQ 2-69)

2. Periods and Rates of Ventilation on Quality of Maine Potatoes. Forced air ventilation through storage bins at rates of 2.4 and 3.0 cfm/cwt. was effective in drying up frost damaged tubers which had been injured in the field. Potatoes stored at 38° with these rates of air movement did not develop soft rot. The color of french fries from stored tubers was darker as the air circulation time increased. Tubers from bins receiving air circulation 12% of the time fried almost as light as the no-air-circulation control; tubers from bins with air circulation 50% of the time fried darkest with those from bins with air circulation 25% of the time intermediate. (MQ 2-92)

Severe surface mold and slight to severe mahogany browning developed in two lots of Katahdin potatoes stored continuously at 32° for 15 weeks or longer. No mahogany browning and very little mold developed when the storage period at 32° F. was interrupted by 1-week periods at 60° so that the longest continuous time at 32° was 3 weeks. (MQ 2-92)

Fusarium tuber rot, Verticillium-pinkeye rot and soft rot were controlled in potatoes stored at 50° F. by using forced air through-ventilation. Excessive shrinkage from desiccation with subsequent pressure bruising, and internal black spot which developed in previous storage studies was greatly reduced by the use of intermittent rather than continuous ventilation after the initial cooling. (MQ 2-92)

3. Control of Sprouting of Potatoes. Irish Cobbler potatoes treated with CIPC (isopropyl-N-(3-chlorophenyl) carbamate) in dips at concentrations lower than recommended for commercial application (0.5 to 1.0%) developed internal sprouts. The most internal sprouting resulted from treatments with emulsions containing 500 ppm (0.05%). At this concentration external sprout growth was inhibited to about 50%, by weight, of that of untreated tubers. As emulsions more dilute than 500 ppm were used more external sprout growth and fewer internal sprouts were found. As more concentrated emulsions were used both external and internal sprout growth was less.

Scrubbing with a detergent followed by rinsing with a stream of hot water, or washing with a stream of hot water adequately removed residue of CIPC from contaminated wooden pallet boxes. The sprouts formed on the tubers stored in the untreated control boxes were of the rosette type, whereas, the sprouts formed by the tubers stored in the treated boxes were normal and vigorous. Washing with cold water was ineffective. (Exploratory)

D. Quality maintenance during transportation

1. Transit Temperature of California Potatoes. When freshly dug Kennebec potatoes were held at simulated transit temperatures in the range of 50° to 70° F., the chip color was lighter as the temperature increased. Tubers held for 9 days at 50° or 55° yielded darker chips than those held for 5 days. However, holding time did not influence chip color when potatoes were held at 60° to 75° F. Potatoes that yielded dark chips after 5 or 9 days at 50° or 55° could not be reconditioned during subsequent holding

for 4 days at 75°. Field temperatures that averaged 51° to 58° F. one week before the potato harvest resulted in darker chips than field temperatures of 72° to 81° F. one week before harvest. Time of harvest (May 5 to June 5 vs. June 23 to July 7) did not influence chip color. (MQ 2-55)

2. Low Oxygen Atmospheres. Freshly dug White Rose potatoes were held 8 days at 59° F. to simulate shipment in atmospheres containing ½, 1, 5% O_2 or air and 8 additional days in air at about 68°. No benefits from reduced oxygen holding were observed. In lots held in ½% O_2, 14 to 30% of the tubers were decayed (bacterial soft rot) at removal; in those held in 1% O_2 0 to 14% were decayed, and none decayed in 5% O_2 or air. Surface mold developed extensively in ½ and 1% O_2, and only slightly in 5% O_2 or air. Black heart affected 12 to 44% of tubers held in ½% O_2, less in 1% O_2 and none in 5% O_2 or in air. Periderm development was inhibited severely in ½ and 1% O_2 and slightly in 5% O_2 as compared to its development in air. This retardation persisted after removal of the tubers to air. Off-flavors and off-odors were severe in ½% O_2, and only mild in 1% O_2, and absent in 5% O_2. The off-odors and off-flavors disappeared during subsequent holding in air for 8 days. (MQ 2-84)

E. Postharvest disease control

1. Hot Water Treatment of Seed Potatoes. A hot water (140°F.) dip for 5 minutes compared favorably with the Semesan bel standard in controlling the new seed borne strain of common scab. However, the treatment markedly reduced yield and plant emergence. A 5-minute dip at 130° F. was ineffective compared with the best chemical treatments. A 5-minutedip at 130° F. before cutting gave excellent control of black leg and Rhizoctonia in pre-cut seed of the Russet Rural variety, and compared favorably with chemical treatments used. B-size whole seed of the Kennebec variety dipped in 130° F. water for 7 minutes showed a significant (5% level) increase in yield of U.S. #1 graded tubers as compared with a dry control. A 5-minute dip in 130° F. water failed to control Fusarium tuber rot (artificially inoculated) in a simulated packing study. (MQ 2-90)

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Quality Maintenance in Handling and Packaging

Hunter, J. H., E. F. Johnston, R. A. Ries, and J. B. Wilson. 1965. An evaluation of hopper-type and dump-type bulk truck bodies for potatoes. Maine Farm Res. 13(2):18-25. (MQ 2-93)

Quality Maintenance in Storage

Hruschka, H. W., P. C. Marth, and P. H. Heinze. 1965. External sprout inhibition and internal sprouts in potatoes. Amer. Potato Jour. 42: 209-222. (MQ 2-31)

Hunter, J. H. and H. V. Toko. 1965. Control of potato-storage diseases as affected by air flow, temperature and relative humidity. Amer. Soc. Agr. Eng. Trans. 8(4):578-580. (MQ 2-35 and 2-92)

Quality Maintenance in Transportation

Johnston, E. F., J. B. Wilson and L. N. Shaw. 1966. A comparison of mechanical bruising and transit temperatures of Maine potatoes when shipped in carloads of 50,000 and 60,000 pounds. Maine Agr. Expt. Sta. Misc. Pub. 674. (MQ 2-42)

Ries, R. A. and H. V. Toko. 1965. Bulk handling and quality evaluation of potatoes shipped in conveyorized railroad cars. USDA-ARS 52-8. (MQ 2-42)

Postharvest Physiology

Craft, C. C. 1966. Localization and activity of phenolase in the potato tuber. Amer. Potato Jour. 43:112-121. (Pioneering Laboratory)

PUBLICATIONS - STATE EXPERIMENT STATIONS

Objective Measurement of Quality

De La Mar, Rosalita R. and F. J. Francis. 1965. Composition of the distillate in the alcohol test for quality of prepeeled potatoes. Proc. Amer. Soc. Hort. Sci. 86:511-516. (Mass.)

Quality Maintenance in Handling and Packaging

Tereshkovich, G. and D. W. Newsom. 1965. Some effects of date of washing and grading on keeping quality of sweetpotatoes. Proc. Amer. Soc. Hort. Sci. 86:538-541. (La.)

Wurster, R. T. and Ora Smith. 1965. Potato quality. XX. After-cooking darkening in potatoes as related to the distribution of radioiron. Amer. Potato J. 42(1):37-44. (N. Y.)

Quality Maintenance in Storage

Davis, C. O. and Ora Smith. 1965. Effect of transit and storage temperature of potatoes on chip color. Amer. Potato J. 42(1):7-14. (N. Y.)

Davis, C. O. and Ora Smith. 1965. Potato quality. XXVI. Darkening of frozen potato products resulting from exposure to ammonia vapor. Amer. Potato J. 42:127-133. (N. Y.)

Kushman, L. J. and F. S. Wright. 1965. Overhead ventilation of sweet-potato storage rooms. N. C. Agr. Expt. Sta. Tech. Bul. 166, 29 pp. (N.C.)

Sawyer, R. L., et al. 1965. Potato storage research on Long Island with forced-air ventilation systems. N. Y. (Cornell) Agr. Expt. Sta. Bul. 1002, 31 pp.

CUT FLOWERS AND ORNAMENTALS

Market Quality Research Division, ARS

Problem. The rapid increase in production of field-grown narcissus, gladiolus, lilies, stocks, and chrysanthemums into a multimillion dollar business in Florida, California, and other states has raised many problems in marketing. Methods of packaging, as related to cooling and market life, temperature requirements during transport and for limited storage periods, atmosphere modifications for storage and transit for both cut flowers and ornamentals, and the control of Botrytis rot are among the most urgent research needs.

USDA AND COOPERATIVE PROGRAM

The Division has a limited program in market quality research on cut flowers and ornamentals, amounting to approximately 2.0 scientist man-years. This research is conducted at the Fresno and Beltsville laboratories and at the Gulf Coast Experiment Station under a cooperative agreement with the Florida Agricultural Experiment Station. The California work is supported in part by the California Floral Traffic Conference and the California Florist Association.

No projects were terminated during the year.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 6 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Quality maintenance in storage

1. Storage Life and Respiration of Daffodils. Field-grown trumpet narcissus (daffodils) were found to have a postharvest life in air of 1 - 2 days at 80° F., 2-3 days at 70°, 3-4 days at 60°, 7-8 days at 50°, 8-12 days at 40°, and 10-21 days at 32°.

Respiration rates of freshly harvested daffodil flowers decreased rapidly to about 1/3 of the original value in 12 hours at 32° or 40° F., then declined very slowly during 3 additional days of storage. At 50 or 60° the rate declined more slowly to about 2/3 of the original rate after 24 hours and remained nearly constant for several additional days. Transfer of the

flowers from 32° and other low temperatures to 70° produced an immediate rapid increase in respiration up to 900% in some instances which usually reached a maximum within 20 hours after transfer. When separated into parts the flowers respired at about 2½ times the rate of the stems and 50% higher than flowers with stems attached. No relationship between the amounts of carbon dioxide evolved in air or in nitrogen and the display life of the flowers was observed. Storage life varied from 3 to 5 days at 60° to 2 to 3 weeks at 32° or 40°. (MQ 2-105)

2. Respiration of Carnations. Low oxygen atmospheres (½, 1, or 2% O_2) reduced the respiration rate of carnations by 45, 40, or 30%, respectively. However, the 2% O_2 atmosphere had very little effect on the quality or post-storage life of the blooms. Holding the stems in water during storage in a normal atmosphere increased the respiration rate by 30%, compared to dry storage. When stored in 1% O_2, respiration of blooms with stems in water was 25% greater than of those stored dry. The effects of low O_2 were sufficient to reduce respiration of blooms in water stored at 1% O_2 below that of those stored dry in air. The deterioration in quality roughly paralleled the respiration rates under these conditions. (MQ 2-105)

3. Effects of Storage Techniques on Gladiolus Flowers. Generally post-storage quality of gladiolus was better as storage temperatures were reduced from 50° to 35° F. or as the length of storage period decreased. Packaging techniques which reduced moisture loss in storage enhanced flower keeping quality. Spikes stored in nitrogen atmospheres were not superior to those stored in air. (MQ 2-117)

4. CA Storage of Carnations. Quality and storage life of carnations was best at 36° F. when the blooms were held in an atmosphere with 1/2 to 1% oxygen as compared with higher oxygen concentrations. A continuous flow of air through the storage chamber maintained quality almost as well as the low oxygen atmospheres and much better than static air in the chambers. More post-storage display life was added by placing the stems of flowers in preservative solutions (compared to water) after storage than by the use of CA or a continuous flow of air during storage. (MQ 2-105)

5. Ethylene Effects on Carnations. Early-season varieties of strawberries from the Fresno area did not produce "sleepiness" in carnations, but when later varieties from the coastal areas of California were held together with carnations for 5 days at 59°, this effect was observed on the flowers after 1 day at 70°. One kilogram of strawberries in a chamber produced about 1.5 ppm ethylene in an airstream (5 ml/min.) which was passed over carnations in another chamber. Preliminary determinations indicate that ethylene concentrations above 1/2 ppm cause sleepiness. A brominated-activated charcoal filter in the line prevented sleepiness. Carnation blooms produced substantial amounts of ethylene when they were "sleepy". Preliminary tests showed that .013 ml of ethylene were produced per hour by 100 grams of sleepy blooms compared to only a trace (unmeasurable) by healthy blooms of the same age. (MQ 2-105)

B. Postharvest disease control

1. Control of Botrytis Decay. Each of the twenty natural amino acids (1,000 ppm) were added to a balanced nutrient solution containing 2% glucose to determine the requirements of Botrytis cinerea. All significantly increased the growth when compared to the nutrient solutions without amino acids. Four analogs were also used in liquid nutrient media. B. cinerea was capable of utilizing only DL-2-methyl leucine. Experiments were conducted to test the effectiveness of certain amino acid analogs used as postharvest sprays for control of B. cinerea on rose (American Red Beauty), gladiolus (Rose Spire) and B. gladiolorum on gladiolus. DL-ethionine at 1000 ppm was effective in controlling B. cinerea infection on rose flowers and gladiolus florets following artificial inoculations. The antimetabolite relationship was demonstrated by a failure to control infection with a 1:1 ratio of DL-ethionine to L-methionine. Exposing conidia to DL-ethionine reduced the percentage of germination and length of germ tubes. Decay reduction with DL-ethionine is fungistatic rather than fungicidal. Infection caused by B. gladiolorum was reduced on gladiolus florets by spraying spikes 1 hour before inoculation with DL-ethionine or m-fluoro DL phenylalanine at 500 or 100 ppm. (MQ 2-117)

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

None.

PUBLICATIONS - STATE EXPERIMENT STATIONS

Objective Measurement and Evaluation of Quality

Rogers, Marlin N. 1965. Chemical growth retardants for poinsettias. Mo. State Flor. News 26(4):3-8. (Mo.)

MARKETING FACILITIES, EQUIPMENT AND METHODS

Transportation and Facilities Research Division, ARS

Problem. Returns to producers and prices paid by consumers for horticultural crops are adversely affected by the use of inefficient marketing facilities, equipment and methods. Better work methods, techniques, devices, operating procedures, equipment, and facilities are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, nuts, and other horticultural crops. Such improvements at shipping points would increase the productivity of labor, prolong the storage life of the commodities, reduce bruises and injuries to these products, reduce marketing cost, expand consumption, and reflect greater returns to producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-range research program covering the development of improved work methods, techniques, devices, operating procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, nuts, and other horticultural crops. Potato research is carried on at the Red River Valley Potato Research Center, East Grand Forks, Minn.; the Potato Handling Research Center, Presque Isle, Me.; a field office at Gainesville, Fla., and the Hyattsville, Md., office; in both laboratory and commercially owned facilities; in cooperation with the North Dakota, Minnesota, Maine, and Florida Agricultural Experiment Stations, the Red River Valley Potato Growers' Association, the Market Quality Research Division, the Agricultural Engineering Research Division, the Marketing Economics Division of ERS, and the Forest Products Laboratory of the Forest Service. Citrus fruit research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural Experiment Station, the Agricultural Engineering Research Division, the Market Quality Research Division, and commercial packers. Deciduous fruit research is carried on by the Wenatchee, Wash., and Athens, Ga., field offices and by the Hyattsville office; in both laboratory and commercially owned facilities; in cooperation with the Washington and Georgia Agricultural Experiment Stations, and the Market Quality Research Division. In Michigan, research on deciduous fruits is conducted under a cooperative agreement and a research contract with the Michigan Station. Vegetable research is conducted by the Gainesville, Fla., and Athens, Ga., field offices, in commercial packing plants and in laboratory facilities of the University of Florida, in cooperation with the Florida and Georgia Agricultural Experiment Stations and with the Market Quality Research Division. Sweetpotato work in North Carolina is conducted under a cooperative agreement with the North Carolina Station. Research on tree nuts is carried on by the Athens, Ga., field office in both laboratory and commercially owned facilities in cooperation with the Georgia Agricultural Experiment Station.

The Federal effort devoted to research in this area during the Fiscal Year 1966 totaled 10.4 scientist man-years (1.1 extramural); 3.2 to potatoes (0.4 extramural); 1.4 to citrus fruits; 3.9 to deciduous fruits and nuts (0.7 extramural); 0.9 to vegetables; and 1.0 to program leadership.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Handling, Degreening, and Packing Citrus Fruit

This research, at Gainesville, Fla., is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling, and packing citrus fruits at shipping points.

A photoelectric reflectance-type color sorting machine was obtained on lease and installed at the USDA Horticultural Laboratory, Orlando, Fla., for tests in cooperation with Market Quality Research Division personnel. Five tests were run on sorting oranges for color with the machine. In each test, the oranges were sorted into four color classes. In two of the tests, each of the four color classes was re-sorted into four more color classes, making a total of 16 color classes, to determine the limitations of the machine and not as representative of practice which might be used commercially. In four of the tests, readings were taken on the sorted oranges with the ratiospect instrument before degreening and at intervals during the degreening process to obtain an indication of the amount of chlorophyll in the rind of the orange. A general trend of decrease was indicated in the mean ratiospect values for each color group going successively from the greenest to the ripest group. The ratiospect readings on the degreened fruit showed the greatest change in chlorophyll level occurred in the group of greenest initial color with less change in groups, going successively from green to ripe.

Tests were made to determine the consistency of sorting with the machine by marking oranges and running them through the machine several times. The percentage of fruit falling in a class other than the original color class (first run) ranged from 9 to 28 percent. This can be attributed to "borderline" cases and to the variation in color on a given fruit since the machine views three points on each fruit but orientation of the fruit may be different each time it passes through the machine.

Two tests were made on sorting limes into color groups simulating what might be done using a color sorting machine preparatory to packing them for shipment. Present practice for limes includes color sorting by visual-manual methods preparatory to packing for shipment.

Preliminary work was done to develop comparative cost relationships between the present degreening method and a projected method of degreening color-classed fruit involving machine sorting.

Data were gathered on additional handling operations in the grove-to-packinghouse sequence. The new data were summarized and related to that

obtained earlier and further work was done in deriving time values needed as a basis for developing comparative relationships to be treated in the planned report on handling systems. Additional film also was taken for adding to the movie on citrus handling systems to fill gaps in the handling sequences. Preliminary findings from recent studies are: (1) Special metal bolsters designed and constructed to move with the load improved efficiency and afforded greater flexibility in loading and unloading operations than fixed bolsters which were generally used. The latter type is made of timbers placed at points where boxes are to be picked up or released and require some additional labor and use of equipment for placing and moving the timbers. However, the movable bolsters do not permit the straddle carriers to pick up less than a full load at any one point which prohibits partial load pickups at other points as can be done when using fixed bolsters; (2) straddle carriers appear to be utilized as effectively as is desirable to justify its investment cost. On occasions, equipment arriving at the grove had to wait until enough filled boxes were ready to make up a load for transporting to the packinghouse. To justify their use, straddle carriers need to be in motion transporting fruit for a very high percentage of the total scheduled operating time. This condition might have been corrected if some means for picking up partial loads was provided; and (3) in a number of packinghouses, the mechanical de-stackers and stackers were still in somewhat of a break-in situation, and their full potential had not necessarily been realized. For example, where there was adequate forklift truck capability to move four-high stacks of filled boxes per trip to the de-stacking unit, the unit was arranged for the input of only two-high stacks of boxes, thus necessitating additional time of a forklift truck to reduce the four-high stacks to two-high stacks and then place them on the de-stacker input conveyor.

Five additional Florida packinghouses adopted pallet-box handling during the 1965-66 season. One of these firms uses large straddle carriers (32 pallet boxes per load) for moving the fruit in pallet boxes from the grove to the packinghouse and returning empty boxes to the grove. Two or three firms took steps to install mechanical de-stackers and/or stackers in connection with their pallet box dumping setup.

Laboratory explorations were made to define pallet box volume-capacity relative to that of the standard field box for use in handling citrus fruit. Miniature containers were made of plexiglass to a scale of one-fourth actual size. Marbles ("fruit") were procured having a diameter approximately one-fourth that of a representative size of orange to use in simulating fruit. The gross volume of each of the model containers (field box and pallet box) was measured by liquid measure. Using the "fruit" the model field box was filled simulating procedures followed in fresh citrus operations and "fruit" was poured into the model pallet box so as to test the volume required in the pallet box for ten of the field box quantities. The volume contained in the voids was obtained by liquid measure with water for each filled field box and for the pallet box containing the total volume from ten field boxes. The ratio of container volume to actual volume of fruit for the pallet box was obtained and compared to the same ratio as developed on the aggregate of ten field boxes. This ratio was approximately .90 when the head space in the pallet box was excluded.

In trials involving the pouring of oranges from field boxes into pallet boxes, at the Florida Citrus Experiment Station, the corresponding ratio to that mentioned above ranged from .895 to .913.

The indications are that a pallet box should provide a volume of (48,000 cu. in. x .90) plus headspace, to have a capacity equal to ten field boxes. This would necessitate a pallet box of 43,200 cubic inches volume for fruit only plus a two-inch headspace. The total volume of the box would be about 46,700 cubic inches. The sum of the volume of ten standard field boxes (as defined under Florida laws) is 48,000 cubic inches. Overfilling of field boxes in the grove can make the aggregate of ten field boxes greater than 48,000 cubic inches.

Pallet boxes already in use, which are marked 10 field-box capacity, have a variation in total volume of from 46,000 to 49,000 cubic inches.

Additional data were obtained on sizing oranges with a transverse expanding-roll sizer and with a new belt-and-roll sizer. The belt speed of 395 feet per minute on the new belt-and-roll sizer is higher with but one exception than that found for any other sizing equipment covered in the earlier studies. One belt-and-roll sizer installed in 1958 had a belt speed of 400 feet per minute. The new sizer referred to above had a higher roll speed (135 fpm) than the older machine (118 fpm) (the exception in respect to belt speed). A comparison of the coefficient of variation values (accuracy) from the study on the new belt-and-roll sizer with those from earlier studies on this type sizer with the high belt speed (400 fpm), shows that there is agreement and that values for the older equipment are as low in general, or lower, than those for the new. Also, the coefficient of variation values for the transverse expanding roll sizer are comparable with those for the belt-and-roll equipment, both old and new.

Preliminary work was begun to determine the feasibility of using ultrasonic cleaning for citrus fruit. Literature on ultrasonic cleaning was reviewed and information was obtained on laboratory-type ultrasonic cleaning equipment from several manufacturers. Samples of "dirty" oranges were sent to two manufacturers of ultrasonic cleaning equipment for cleaning tests in their laboratories.

B. Handling and Packing Deciduous Fruits

This research is directed toward the development of more efficient work methods and equipment for handling, washing, sorting, sizing and packing apples. It includes studies on the impact of electronic color sorting of apples on related packinghouse operations, an evaluation of presizing and presorting apples in commercial storages and packinghouses, and the development of new equipment for prestorage sorting and sizing of apples.

1. At Wenatchee, Wash., construction of an improved packing line designed around a unitized brush-sizer was completed and installed for testing under commercial operating conditions in a commercial apple packinghouse at

Monitor, Wash. Trial runs of this unit showed that several changes and modifications were necessary. Considerable redesign work was done on the elevating rollers; their surface material was changed from foam rubber discs to solid polyurethane, the elevating angle was increased slightly, and pusher bars were installed to operate between rollers at the discharge end. The original brush material was not satisfactory, and replacement brushes specified to much closer tolerances were obtained. Results of preliminary trial runs indicate that the principles and innovations incorporated in the unitized brush-sizer are sound but that further tests are needed. A manuscript for the interim report, "Sorting and Sizing Apples with Brushes," was prepared and submitted for editing.

Work on a roller-type pallet-box filler involved experiments with different arrangements of rollers and distributor pans in an effort to arrive at a combination that would permit rapid filling of the box with an absolute minimum of bruising of the fruit. An arrangement currently under investigation employs a series of helices instead of rollers to lower fruit into the pallet box. This arrangement gives good results in discharging fruit into the pallet box, but the feed-in arrangement needs further refinement.

Work on electronic color sorting of apples was devoted almost entirely to the preparation of a manuscript presenting the results of completed work; including data on the operation, layout, and fruit handling features of the electronic color sorter. The cost of ownership and operation at selected annual volumes (100,000, 200,000, and 500,000 bushels), as well as the effect of electronic color sorting on other packing line operations, will be shown. Also, effectiveness of the electronic color sorter as it relates to accuracy of color separations, capacity under different conditions, amount of bruising it causes, and utilization of the labor force.

2. At East Lansing, Mich., editing of the Michigan Station's final report, under a cooperative agreement, covering theories and principles of the use of water as a medium for dumping, sorting, sizing, and filling apples into pallet boxes was completed and published as Marketing Research Report No. 743, "Development of a Hydrohandling System for Sorting and Sizing Apples for Storage in Pallet Boxes."

Under a research contract, Michigan State University, prepared and submitted detailed working drawings, together with a drawing of the system as a whole, for a prototype hydrohandling system for prestorage sorting and sizing of apples. The prototype handling system was designed to sort and size orchard-run fruit at the rate of 600 bushels per hour. The system includes all the necessary components for emptying pallet boxes, sorting and sizing the fruit and filling the fruit back into pallet boxes. All operations, except sorting, are to be performed in water.

Construction of the prototype hydrohandling system for the prestorage sorting and sizing of apples was completed by March 31, 1966.

Tests of individual components of the system were conducted under laboratory conditions to determine proper synchronization of the output of all components, and as a basis for minimizing possible bruising and damage to apples, achieving desired overall rates of operation, and modifying or rebuilding the system to remove or eliminate mechanical and other defects. The complete system was moved to and installed at a commercial apple packing and storage house at Belding, Mich., where a series of tests were run with storage fruit.

Color movies of the equipment in operation were made for record purposes only. A demonstration of the system was arranged in cooperation with the International Apple Association on June 15, 1966, and over 200 people associated with the apple industry viewed the equipment in operation. Great interest was shown by those observing the prototype equipment and how it performed.

A manuscript entitled "A Prototype Hydrohandling System for Sorting and Sizing Apples Before Storage" was prepared and will be published as ARS 52-14. It is scheduled for release on August 10, 1966.

3. At Athens, Ga., additional work on the study to develop layout guidelines for commercial peach packinghouses involved minor revisions to the layout drawings and rewriting portions of the manuscript for a report on the research findings. This report entitled "Layout Guidelines for Peach Packinghouses" presents a systematic layout procedure that should be followed and factors that should be considered when developing layouts for peach packinghouses. Operating procedures and basic plant layout principles are illustrated by three layout examples that were developed for synthesized operations.

An evaluation of methods and equipment for handling peaches during receiving and dumping operations was continued. Studies were conducted in commercial peach packinghouses to obtain additional data on the labor and equipment requirements for handling peaches in pallet boxes. Labor and equipment costs for the pallet box method were determined and compared with the costs for handling in field boxes by clamp trucks. Results indicate that the average size packer cannot economically justify pallet box handling when using dumping equipment that is presently available. Labor costs are high and the flotation dumping principle, which the dumpers incorporate, is not acceptable from the standpoint of effectiveness and maintenance of product quality. A synthesized method, using a principle that dumps the peaches out of the pallet boxes into water, was developed and handling costs estimated. Preliminary results indicate that, if a dumper of this type was available, the use of pallet boxes could be economically justified for most peach handling operations and would result in a considerable savings to the industry.

A study to compare the cost of precooling peaches in bulk hydrocoolers with that for flood-type hydrocoolers was initiated during the year. Bulk and flood-type hydrocoolers were designed to cool 210, 420, and 840 bushels of peaches per hour under identical operating conditions. Computations of labor and equipment costs for each method at each volume level were begun. Results of this study will aid packers in selecting hydrocooling systems that will perform efficiently and economically.

C. Handling and Packing Potatoes

1. Presque Isle Me. Research under this project is directed toward reducing operating costs of potato storages and packinghouses by increasing the productivity of labor employed and reducing losses from bruises and mechanical injuries in handling, storing, cleaning, grading, sizing and packing potatoes. It involves the development of more efficient work methods, operating procedures, equipment, and facilities for handling, storing, and preparing for market Maine potatoes.

Because of a vacancy that existed in this one-man office, the progress reported is limited to that on joint work and under a cooperative agreement.

Joint work was continued on the preparation of a manuscript, "Supplying the Packing Line with Potatoes in Maine Storages at Rates of 200 Hundredweight Per Hour and Above."

Under a cooperative agreement, the Maine Agricultural Experiment Station conducted research looking forward to the designing and building of a new and improved sizer for "long" white potatoes. In connection with this research, measurements of length, depth, height, and weight were made of 6,054 "long" potatoes. Potatoes from the major producing areas (California, Idaho, Maine, and Red River Valley) were included in the sample, which proved statistically reliable. Analysis by use of computers was made to extend the data which show the nature of the sizing characteristics of "long" potatoes.

A patent search was made to determine the state of the art of sizing potatoes and to take advantage of other developmental work already completed. Ideas on these patents were evaluated. Various kinds of sizing apparatus also were investigated as potential principles to be used in designing an improved sizer, including: (1) Mechanical devices; (weight, dimension, and other); (2) electronic; and (3) light. After the principles were evaluated, a "mock-up" was made of the most promising for the purpose of pretesting the principle and determining its potential.

2. Gainesville, Fla. Research objectives at this location are the development of more efficient work methods, operating procedures, and equipment for the handling and preparation for market of potatoes in spring-crop areas.

The manuscript, "Bulk Handling Spring Crop Potatoes from Harvester to Packing Line--Methods and Costs," was completed and sent to the Government Printing Office in June. It will be published as Marketing Research Report No. 761 and will be released during the first half of the next report year. The bulk-dumping system has a cost advantage of $18 per one thousand packed hundredweights of potatoes over a pallet box handling system, and $14 over the conventional hopper-body sloping-bottom bin system. With the bulk-dumping system multiple use can be made of trucks and bin facilities.

Following completion of work on the bulk-dumping system, a statement was prepared on the "Possible Areas for Application of Research Effort--Potato Handling and Packing." After internal review, the statement was sent to a

representative of the Florida potato industry asking for appraisal and comments. Subsequently, a conference was held with representatives of the industry, who recommended that future work be directed towards: (1) Developing a higher degree of mechanization in packinghouse equipment for handling the potatoes; (2) developing more fully mechanized means of packaging the potatoes (filling and closing bags, for example); (3) evaluating the possibility of shipping the potatoes in bulk and eliminating the conventional packaging; and (4) consideration of greater use of pallets and unit-load handling for the bagged potatoes to reduce manpower requirements in the packinghouse. These areas will be considered, along with other significant industry proposals, in planning and allocating available resources.

Arrangements were made for conducting work-sampling studies on the bag filling, closing, and take-away operations at two different packinghouses at Hastings, Fla., to obtain data to evaluate machine sewing of bags against the conventional method of hand sewing. One of the packinghouses uses a new carrousel-type filling machine for 50- and 100-pound bags (burlap being used) for the second season; the other had a conventional setup of fixed bagging heads and scales along a belt conveyor. The first house made a limited trial of machine sewing for closing bags at the beginning of the season and then resumed hand sewing. The second used hand sewing for closing bags, the conventional method of long standing for potato packinghouses. These studies were only partially completed because the work was initiated too near the end of the potato packing season to find consistent operations.

3. Red River Valley Potato Research Center, East Grand Forks, Minn. Work is directed toward developing more efficient work methods, techniques, devices, and equipment for the handling and preparation for market of midwestern fall-crop potatoes.

The manuscript, "Handling Potatoes from the Storage to the Packing Line," is estimated to have been about 60 percent completed. However, because of a shift in planned work and other activities, a new estimate of a completion date for this manuscript is during the third quarter of the next year.

Studies in commercial plants in the Red River Valley doing both "wet" and "dry" grading, were completed. The information gathered provides valuable details about typical storage and wash line operations.

Research to determine bulk truck transit temperatures was completed. Preliminary analysis of the test data indicates that the air temperature in bulk truck loads of potatoes changes only slightly while the load is moving from field to storage under the usual harvest conditions. Even with uncovered loads, the difference between the initial load air temperature and the ambient air temperature must be as low as 10 to 20° F. before any marked change in load air temperature occurs during transit. Then the change is peripheral only.

Research on cleaning and sizing fall-crop potatoes before storage was limited to analysis of data obtained from tests during previous seasons. The

preparation of a manuscript concerning the feasibility of sizing potatoes into storage was initiated.

Because individual workers showed excessive variation when hand sizing samples of potatoes by use of standard sizing rings, a new sizing device consisting of an array of cylinders of appropriate diameter through which the tubers are passed was designed and constructed. No tests were made with the unit during the report period.

D. Handling and Packing Vegetables

At Gainesville, Fla., this research has as its objective the development of improved work methods, devices, and operational procedures for the handling and preparation for market of vegetables at shipping points.

Tests were conducted of a small package continuous-motion check-weigher having a series of conveyors to feed and take celery stalks away from the weigher. This equipment was purchased during the previous report period with trust funds under a cooperative agreement.

In the initial tests of the machine, in the Agricultural Engineering laboratory at the University of Florida, the feed and take-away belt conveyors were regulated and the entire system was checked for handling problems. Additional laboratory tests determined the zone edge tolerance or weighing accuracy of the scale. At a belt speed of 377 feet per minute the zone edge tolerance was $\pm$16.5 grams (0.036 pounds).

These tests indicated that stalk spacing would be a problem, because if two stalks had less than 8 1/2 inches between them, the second stalk would not be properly classified. Several combinations of belt speeds on feeding and spacing conveyors were tried in an attempt to improve regularity of stalk spacing. An optimum spacing of 9 1/2 inches between stalks at a feeding belt speed of 408 feet per minute was best for a production rate of 200 stalks per minute.

Field tests were made with the equipment in the plant of the grower-cooperator at Belle Glade, Fla. Celery stalks were conveyed over the scale and a good breakdown of sizes obtained. Other tests were made to check stalk spacing and several movies were made of stalk action on the belt conveyors, on the weigh scale, and in the feed chute. Based on these movies, an improved celery drop chute was designed and installed for further tests.

Another type of scale, a mechanical beam-type, was also evaluated. It included an overhead monorail conveyor from which several regularly spaced stalk carriers were suspended. The zone edge accuracy of this type scale was approximately $\pm$0.2 lbs.

Statistical analysis of the weights of celery stalks classified by the mechanical beam-type scale indicated that this scale had sufficient inaccuracies to give a weight range of about 1 1/2 lbs. per crate for each celery size classification; whereas a range of less than 1/2 lb. is desired. Probability of over- and under-sized stalks was 30 percent.

A feasibility study was made of several types and sizes of containers to handle celery in bulk from the field to a central packinghouse. Pallet boxes, trailers, and bulk trucks were compared. Conclusions were that a large container would be desirable.

A bulk handling study was made to determine maximum container depth in which celery could be handled without excessive physical damage. The stalks were carefully stacked in oriented arrangement on the floor of a 4-foot deep, 7-foot wide and 14-foot long trailer in two-, three- and four-foot depths.

Results were that there was no increase in frequency or severity of injury depending upon the location within the trailer, at different depths, within the pile. Evaluation of the stalk damage indicated that 42 percent of the stalks would receive no damage whatever. Also, that 35 percent of the stalks would have only one cracked petiole on what would otherwise have been a marketable petiole. Most important, however, was the indication that only 5 percent of the stalks would have minor scoreable damage (damage scored against quality by the State inspectors) and only 1.3 percent of the stalks would have major scoreable damage.

Based on these results a 4-foot deep and 20-foot long trailer was designed, built, and field tested in conjunction with a mechanical harvester which had been designed and built by the grower-cooperator. A second evaluation of celery stalk injury showed even less handling injury than during the initial study. In the field tests 56.7 percent of the stalks received no damage whatever.

Prior to the packing season, several types of workplaces for packing celery into wirebound crates were evaluated by predetermined-elemental-time data. Several packing methods were compared and the most promising methods were selected for further work. In the pilot packing plant, a belt packing system, although not the method requiring the least labor requirements, was installed to fit the layout and sizing system which was used. Time studies were made of workers packing crates at these work stations and these results were compared with labor requirements predicted by the predetermined time system.

Trials were also made of improved celery packing stations. Good worker acceptance of the new methods was obtained. Time studies were not made of these packing systems. However, exact descriptions were made of workers' motions while packing crates at some of the trial packing stations. Further evaluation of packing time requirements were made of these improved stations by use of elemental time data. The best system which was evaluated required 0.665 minutes per crate as compared to 1.835 minutes for the packing station installed in the pilot plant at Belle Glade.

A packinghouse layout incorporating the celery dumping tank, the electronic weigh scale, and the improved packing stations has been developed and will be incorporated into a report planned for the next year.

The photoelectric reflectance-type color sorter, obtained primarily for tests on citrus fruit, was modified to sort vine-ripened tomatoes into color groups. Several tests were conducted to sort tomatoes into from 4 to 13 color classes. In all cases, the tomatoes in each color group ripened quite uniformly except for the ones in the last group which were a mixture of green and "breaker" fruit. The machine was unable to sort green from breaker fruit with good consistency because of the random orientation of the tomatoes with respect to the viewing system.

The effect of the machine on bruising injury to the tomatoes was investigated by comparing a quantity of machine color sorted fruit with an equal quantity of unsorted fruit after ripening. No significant difference in the amount of bruising was detected between the sorted and the unsorted fruit.

The biospect instrument at the University of Florida Food Science laboratory was used to plot curves of optical density versus wavelength (500 to 875 nanometers) for light transmittance and reflectance tests on tomatoes at selected intervals during ripening process to obtain information necessary for selecting the best combination of wavelengths for evaluating the ripeness of vine-ripened tomatoes with the ratiospect instrument at the Orlando, Fla. laboratory. The ratiospect instrument measures the amount of light reflected by or transmitted through a sample at two selected wavelengths, and the difference in the amount of light transmitted or reflected at the two wavelengths gives a single reading as an indication of tomato ripeness.

E. Storage of Deciduous Fruit

1. Room Cooling Rates. The purposes of the research, at Wenatchee, Wash., are to: (1) Measure and evaluate the cooling rates of fruits stored in shipping containers of designs that should properly protect the fruit, shorten the cooling period, and maintain the fruit at proper storage temperatures; and (2) develop improved handling, stacking, and storage practices.

Cooling rate studies were run on packed boxes of apples as in previous years. A standard fiberboard box of tray-packed apples was used for a comparison, or check. One of the test boxes, 5-S, had enlarged vent holes in each end. The standard vent holes were increased in size from 1 1/2 by 1/2 inch to 1 1/2 by 1 inch and an additional hole, 2 1/2 by 1 inch, in the center of each end was added. In the other box tested, 6-S, special holes were placed in each end as follows: one oblong slot, 1 1/2 inch down from the top of the box, 4 inches long by 1 inch wide with rounded ends and centrally located, and three additional holes 2 inches in diameter were located in each end; one located centrally in the end and one in each lower corner 3 1/2 inches in from the sides and 1 1/2 inches up from the bottom. All fiber trays used in these tests were perforated. A second test was run on the same boxes using Dow plastic nonperforated trays. Although data from these tests have not been completely analyzed, indications are that the cooling rate on the box with the large holes is the best. As in previous tests, plastic balls filled with water were used in lieu of apples at the locations where temperatures

were measured. Previous study has shown that these balls cool at the same rate as apples of comparable size. By using this method, tests can be repeated and duplicated as the temperature measuring points are not influenced by the fruit. When apples are used, their cooling properties change after each test when they are warmed up and recooled.

2. Refrigerated Storage. The objectives of the project at Wenatchee, Wash., are to: (1) Investigate airflow and distribution methods, patterns, and rates in refrigerated fruit storages to determine and evaluate the influence of these factors on cooling fruit and bringing it to optimum storage temperatures; (2) determine and evaluate heat gain through various structural features of fruit storages and make suggestions for improved designs; (3) redesign storage houses for the most efficient handling and storage of fruit in pallet boxes; and (4) evaluate hydrocooling of apples before they are placed in storage.

A check on a cold storage room to determine air temperature patterns in a low ceiling room filled with apples was made by placing thermocouples at different places in the room and measuring the temperatures periodically over a period of three months.

Inquiries were made on the acceptance of air curtain doors by the apple storage houses in the Pacific Northwest to provide the basis for an article, "Air Curtain Doors and Their Use in The Pacific Northwest," for the American Fruit Grower for publication in one of the fall issues.

3. Controlled Atmosphere Storage of Apples. Work on this project is designed to develop improved methods, techniques, equipment, and facilities for the controlled atmosphere (C.A.) storage of apples in the Pacific Northwest, and is in cooperation with the Market Quality Research Division.

Observations were continued on the commercial storage of apples in controlled atmosphere (C.A.). The types of C.A. storages being investigated at the present time are: (1) Regular C.A., which uses caustic soda as a scrubbing material to remove carbon dioxide (CO_2) from the room atmosphere. This system requires an airtight room, first cost of construction is high, and requires close attention during operation; (2) Tectrol C.A., which delivers correct atmosphere to the room. This is expensive equipment but can now be bought. With this system rooms do not have to be sealed airtight (one air change in two days is allowed), quick pulldown to desired atmospheric conditions is possible, and room can be opened at any time to take out samples; (3) desomatic absorber or molecular sieve which uses a burner to remove oxygen from the air. This unit can be purchased and owned. The molecular sieve removes all impurities from the room air, requires the installation of a humidifier to maintain proper relative humidity in the room, and is also capable of quick pulldown; (4) water scrubber to remove CO_2 from room atmosphere. This system must have an airtight room and has a high first cost. It is not recommended for rooms where the temperature is low or the CO_2 content of the room has to be less than 2 1/2 to 3 percent; (5) lime scrubber uses slack lime as a scrubber to remove the CO_2 from the air. Lime can be

left in the bags, requires airtight rooms, and disposal of used lime could give some problem unless there is need for it in the area.

F. Storage of Potatoes

Work under this program, at the Red River Valley Potato Research Center, is directed toward providing optimum storage conditions for fall-crop potatoes for table stock, seed, and processing; and developing improved layouts and designs for potato storage houses, which will permit the use of the most efficient handling and packing methods, keep injuries and mechanical damage to a minimum, and minimize construction and maintenance costs.

1. For Table Stock and Seed. Plans and specifications were completed and distributed for a 20,000 cwt. arched roof potato storage. These are identified as Potato Storage, Plan No. 5989, through the Cooperative Farm Building Plan Exchange. Sixty-two sets of reproducibles have been distributed throughout the United States. The plans consist of eight sheets of design drawings and sixteen sections of specifications.

The plans consist of one bin with a storage capacity of about 20,000 cwt. and a work area (1,600 square feet). As designed, the storage can be used for storing processing potatoes or seed potatoes.

Designing, drafting, and specification writing are about 75 percent completed on a 60,000 cwt. long bin, cross alley, potato storage. On a 30,000 cwt. pallet box storage the designing, drafting, and specification writing are about 40 percent completed. There are eight plates in each set of plans.

To facilitate better publicity of the 60,000 cwt. door-per-bin storage and the 20,000 cwt. arched roof potato storage, manuscripts were prepared for miscellaneous publications for each of these designs. Also, a three minute color T.V. film was prepared for distribution to 400 T.V. stations throughout the United States to further the publicity of the 60,000 cwt. door-per-bin potato storage.

Several types of metal and wood bin fronts with roll-out retainers were installed at the Potato Research Center. The tests indicated that these types may have limited application for low pile depths but are not satisfactory for a high pile depth.

A bulletin on fall-crop storages was about 90 percent completed.

2. For Processing. A new fan and a duct system were installed to obtain more uniform through ventilation for purposes of comparing a combination of shell and through ventilation to shell ventilation in 55° F. bulk storage bins.

Preliminary data indicate a greater range of relative humidity within bins than between bins receiving these different types of ventilation. The bin

with through ventilation appears to have more of a range in relative humidity between the bottom and the 12-foot high surface than the bin having only shell ventilation.

Areas of tuber breakdown due to rotting occurred in the bins receiving both types of ventilation. Breakdown was more severe in the shell ventilation bin. Through ventilation should arrest the breakdown, but would not dry it up unless low relative humidity (60 percent or less) air was used. Increasing the air flow rate from approximately 0.7 c.f.m./cwt. to 2.0 c.f.m./cwt. had little apparent effect. It was found that in a breakdown area where there was free moisture, thermocouples did not immediately indicate a significant temperature change.

In an attempt to simulate small scale bins, 55-gallon capacity drums were assembled into 12-foot high columns which received the following ventilation rates; 2.0 c.f.m./cwt., 0.4 c.f.m./cwt., and gravity flow. Air temperature and tuber data were collected. These data have not been evaluated as yet for comparative purposes.

Nine control chambers were built to evaluate the effect of air velocity and relative humidity on potatoes during long-term storage. The levels of relative humidity maintained were 92, 85, and 75 percent with air velocities of zero f.p.m., 75 f.p.m., and 150 f.p.m. The data collected on weight loss, dimensional changes, and specific gravity have not been summarized.

G. Cooling Deciduous Fruits

This research is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient cooling of deciduous fruits.

At Wenatchee, Wash., the purpose of this project is to determine the possible advantages and disadvantages of hydrocooling apples prior to storage. Three varieties of apples were again used in tests conducted during the fall of 1965: Golden Delicious, Starking Delicious, and Winesaps. Samples consisting of two standard boxes of apples were hydrocooled to a core temperature of 40° F. by immersing the boxes of apples in a tank of water and crushed ice. Other lots were hydrocooled to a temperature of 40° F. at 1/2 inch below the skin surface. The temperatures were determined by inserting thermocouples in the center apple of the box and temperature readings taken with a potentiometer. When the thermocouple indicated a temperature of 40° F. the boxes were removed from the ice bath and placed immediately into storage at 30 to 31° F. and a relative humidity of 87 percent. The Golden Delicious apples were packed in fiberboard boxes using polystyrene trays and polyethelene liners before they were placed in the cold storage room. Other boxes of apples of each variety were cooled as follows: (1) To a core temperature of 35° F. in 3 days, then placed in the cold storage (30 to 31° F.) room; (2) to a core temperature of 35° F. in 7 days, then placed in the cold storage room; (3) to a core temperature of 35° F. in 14 days, then placed in the cold storage room; and (4) to a core temperature of 35° F. in 28 days, then placed in the cold storage room.

Temperature records were kept and the apples sampled periodically during the storage season, pressure tested, and rated by a taste panel. The tests indicate that Delicious apples cooled in 28 days had a storage life of about 40 days, while those cooled in 14 days could be held for longer periods but had a poorer quality when compared with the faster cooled apples. There was but little difference in the storage life and quality of apples cooled: (1) In 7 days, (2) in 3 days, (3) hydrocooled to a core temperature of 40° F., and (4) hydrocooled to a temperature of 40° F. 1/2 inch below the skin surface. The one exception was Winesap apples; all samples attained about the same rating during the storage season. The dessert quality had improved at the end of the storage season.

Some internal core rot was found in the hydrocooled Starking Delicious and Golden Delicious apples. This indicates that water may have entered the open calyx during hydrocooling.

The May inspection of Golden Delicious apples showed considerable decay in the box of apples that took 28 days to cool. Considerable storage scald was found in all lots.

All test varieties will be held until they break down or decay indicating the end of their storage life. This will show if hydrocooling extends the storage life of the apple.

At Athens, Ga., tests of precooling peaches with the experimental, prototype, forced-air precooler were conducted. Malfunctioning equipment and operating difficulties prevented the attainment of high-level performance in the forced-air precooling of peaches in wirebound boxes. However, 2-inch diameter Maygold peaches, fed through the cooler in wirebound boxes at the rate of 35 hundredweight per hour, were cooled from 79° F. to 53° F. in 40 minutes. Efficiency, in terms of heat removed per heat equivalent of electrical energy input, was 50 percent. Power cost at 3 cents per kw. hr. was 4.25 cents per hundredweight.

H. Cooling Citrus Fruits

At Orlando, Fla. and Athens, Ga., research on thermal properties and heat transfer characteristics of Marsh grapefruit was continued. Thermal properties data were analyzed from fifty test runs of Marsh grapefruit consisting of ten runs each for five maturity groups. The analyses included: (1) Development of mathematical expressions for the internal temperature, with respect to time and distance from center, during ideal cooling; and (2) correlation of thermal property on moisture content, density, and seasonal effect. None of the correlations were significant at the 95 percent level of probability, nor were there found any effects of maturity on the heat transfer characteristics of the whole specimen. Solution of a prediction polynomial for one maturity group resulted in a half-cooling time of 38 minutes (based on mass-average temperature) for grapefruit cooled in agitated water at 32° F.

At Gainesville, Fla. the manuscript, "Forced-Air Precooling of Florida Citrus Fruits," was edited and revised for publication as a technical bulletin. This manuscript now has the title, "Performance of an Experimental Forced-Air Precooler with Florida Citrus." The basic findings included in this manuscript were reported during the last report period.

The portable, prototype, forced-air precooling unit, mentioned above, was moved from Hertford, N. C. and installed at the Citrus Experiment Station, Lake Alfred, Fla. Under a cooperative agreement, the Florida Citrus Experiment Station conducted and supervised planned cooling research.

The first period of experimental work involved fruit in various kinds of containers. Test runs were made with oranges, Temples and grapefruit, for a small and large size of each of the kinds of fruit. Containers included 4/5-bushel cartons, 4/5-bushel wirebound crates, 5-pound poly bags, 5-pound mesh bags, and shrink film trays. A total of about 200 test runs were made.

Another period of experimental work involved cooling fruit in bulk. A series of test runs were made. Although analysis of the data has not been completed, preliminary results are: (1) Initial and final air temperatures were measured in the five stages of the forced-air precooling unit during a test run with no fruit. The variations between the initial and final temperatures have been attributed to icing of the cooling coils. This indicates what might be a problem for a commercial installation in continuous operation unless some means of automatic defrosting is included in the design; (2) power consumption showed a highly linear relationship between power consumed and time. In a 5.50-hr. test run, 215 kwh were used; (3) for small and large size pineapple oranges (216 and 126, respectively) cooled in open 4/5-bushel wirebound boxes, both the center and mass average temperatures were consistently higher for the large size throughout the range of cooling. The differential in temperature between sizes of fruit was approximately 5° F. at the center and 8° F. at the mass average point. More important, however, is the amount of difference which was shown between the center and mass-average temperatures for each size of fruit, ranging from 12 to 20 degrees after about 20 minutes of cooling; (4) for oranges in containers, the cooling rates (degrees F. per minute) determined from preliminary calculations showed considerable variation from container to container; and (5) for oranges in bulk, the cooling rates averaged 0.81 for five runs. Exposure times of 17, 20, and 33 minutes were included and fruit sizes were approximately 200 and 163. Power consumption ranged from 0.94 to 1.30 watt hours per pound per °F.

I. Cooling Vegetables

This research at Athens Ga. and Gainesville, Fla., is designed to develop improved methods, operating practices, and techniques for use in existing and new facilities for more efficient cooling of vegetables.

Editing and preparing for publication the manuscript covering research on

hydrocooling stacked crates of celery and sweet corn was completed. This manuscript now entitled "Hydrocooling Stacked Crates of Celery and Sweet Corn" will be published as ARS 52-12 and is scheduled for release early in August 1966.

Tests of precooling vegetables with the experimental, prototype forced-air precooler were conducted at Hertford, N. C. The temperature at the center of bushel hamper baskets of snap beans, fed through the cooler at a rate of 32.5 hundredweight (cwt.) per hour, was reduced from 85° F. to 55° F. in 30 minutes. At the mass center of the basket, the temperature was reduced to 50° F. This cooling was accomplished at an efficiency of 62.5 percent and at a power cost of 4.5 cents per cwt., assuming 3 cents per kw. hr. Sweet corn, tightly packed in wirebound crates, was cooled from 81° F. to a mass-average temperature of 70° F. in 17 minutes. This temperature reduction in 115 cwt. per hour resulted in an efficiency of 70.5 percent and a power cost of 1.3 cents per cwt.

Five test runs on single specimens of sweet corn with the husk intact and three test runs on single specimens with the husk removed and sealed with "Saran Wrap", were conducted in a specially designed laboratory forced-air precooling test facility. Rates of airflow, in terms of approach velocity, were 250, 500, and 750 feet per minute. Constant air temperatures used were 18° F., 20° F., 22° F., 25° F., 27° F., and 30° F. In these tests the cooling coefficients ranged from 1.8 to 2.0 (degrees per hour per degree difference) for unhusked corn and from 3.0 to 5.1 for husked corn. The half cooling time for these same tests ranged from 20.6 to 23.4 minutes for unhusked corn and 8.2 to 14.1 minutes for husked corn.

Preliminary investigations of an exploratory nature were begun on research to measure the basic thermal properties and heat transfer characteristics of sweet corn. No findings are available from this work as yet.

J. Handling Vegetables in Pallet Boxes

1. Tomatoes. Recent developments in the production and harvesting of tomatoes, such as mechanical harvesting for processing, has brought about an urgent need for the development of larger containers than field boxes for handling this commodity. Because of this need, research on handling and ripening tomatoes in pallet boxes was undertaken at East Lansing, Mich., under a cooperative agreement with the Michigan Agricultural Experiment Station.

Research on this project was confined primarily to revising the manuscript, "Handling of Tomatoes in Pallet Boxes," based on the final report submitted under the above agreement.

2. Sweetpotatoes. This research is designed to increase the efficiency and reduce the unit cost of handling, curing, storing, and preparation for market of sweetpotatoes and to minimize losses from spoilage and deterioration. This work is being conducted at Raleigh, N. C., under a cooperative agreement with

the North Carolina Agricultural Experiment Station and the North Carolina State Department of Agriculture.

During the report period, research on this area was confined to the completion of a manuscript entitled "Optimization of Sweetpotato Harvesting and Handling Methods by Unit Flow, Shortest Path Techniques" which contains the details of the research covered under the above agreement.

Steps were taken toward preparation for publishing the final report covering the research conducted under this agreement.

K. Handling and Preparing Pecans for Market

This research at Athens, Ga., is directed toward developing more efficient work methods and operating procedures, equipment, and devices, for the handling and preparation for market of pecans in producing areas of the Southeastern United States.

Since this is a new area of research, a literature review was conducted to determine what work has been done toward improving methods and equipment for handling and preparing pecans for market. It was found that a considerable amount of work has been reported on the production and harvesting aspects of handling pecans, but practically no work on the shelling plant operations.

Commercial shelling plant operations were observed to become familiar with equipment, work methods, and operating procedures in use for the purpose of isolating problem areas. Results indicate a need for work aimed at improving the cracking operation. Commercial crackers on the market do not consistently yield a high percentage of halves; therefore, a considerable amount of labor and equipment is required for separating the halves from the pieces and handling them separately throughout the packing operations. It was found that the yield of halves may vary from 50 to 75 percent.

Preliminary investigations indicate that the variation in yield of halves may be because the variation in pecan length within a diameter size class is greater than the adjustment for length on the available crackers. Pecans are sized by diameter only and the crackers are adjustable for a one-sixteenth inch variation in length.

A study was conducted to determine the relationship between pecan length and diameter for eight varieties. One hundred nuts of each variety were randomly selected and the length and diameter of each pecan was measured. The data were statistically analyzed by computer. Results showed a low correlation between length and diameter for all varieties, which indicates that pecan length cannot be predicted within a sixteenth of an inch based on diameter. For example, if a cracker is set for the mean length of a diameter size class, only 30 percent of the nuts would be within 1/16-inch of the mean. This information will be useful in developing design criteria for an improved pecan cracker or better utilizing existing ones.

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CONSUMER PACKAGES AND SHIPPING CONTAINERS

Transportation and Facilities Research Division, ARS

Problem. It costs about 8 billion dollars a year to package food products, but without shipping containers and various other types of packages it would be impossible to move farm products efficiently from the widely dispersed areas of production through our complex marketing system to millions of consumers. New or improved packages and containers must be developed and evaluated to do this job more effectively. Continuing changes characterize the American marketing system. In protecting, distributing and selling perishable agricultural commodities, packages, and containers must respond to a number of marketing system changes. Such changes include:

*Changes in consumer preference--from buying unpackaged items to buying in packages with convenience features such as ready-to-cook spinach.

*Changes in distribution practices--from service grocery stores to self-service supermarkets.

*Changes in forms of transportation--from surface to air where light-weight containers are essential.

*Changes in handling methods and equipment--from warehouse stacks as high as a man to multi-pallet stacks.

*Changes in protective services--from water ice to vacuum cooling, which permits use of cheaper containers.

*Changes in market organization--from buying at terminal auction to buying f.o.b. shipping point, which permits the economies of jumble-packing instead of costly face-packing.

*Changes in market outlets--increased emphasis on selling many agricultural products in foreign markets.

Packages and containers not only respond to changes, but changes in them stimulate improvements in other parts of the marketing system. The job of the research program in this area is to see that packages and containers keep pace with changes in the marketing system and reduce the cost of handling, transporting and storing agricultural commodities. It also seeks to improve service to consumers, promote greater sales of farm products, and increase the income of producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing program of applied research conducted by marketing specialists, industrial engineers, and agricultural economists to (1) develop new or improved consumer packages, master containers, packing materials, and shipping containers for domestic and export marketing of agricultural products; (2) evaluate them from the standpoint of cost of materials and direct labor to pack, and their ability to reduce product damage and increase product salability; (3) determine at which point in the marketing system packaging can be done most effectively; (4) improve the efficiency of packaging methods to cut costs; and (5) investigate the needs for and benefits of container standardization and simplification. Current packaging and container research is on deciduous fruits, citrus fruits, vegetables, cut flowers, poultry and dairy products. The program is carried on in cooperation with experiment stations and industry in California, Oregon, Washington, New York, New Jersey, Pennsylvania, South Carolina, Delaware, and Florida; at field stations in Orlando, Florida; Fresno, California; and Yakima, Washington; in other main producing areas; and in the principal terminal markets. This program involves 9.9 scientist man-years: (a) Fruits and vegetables, 4.2; (b) cut flowers, 0.7; (c) export shipping containers for produce, 1.9; and (d) standardization and simplification of shipping container, 2.2.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Shipping containers and packages for fresh fruits and vegetables

1. Apples. Shipping containers for Winesap apples in polyethylene bags--Four types of apple boxes were evaluated for shipping twelve 3-pound bags of Winesap apples. They were: (1) a conventional two-piece full-telescope box; (2) a one-piece box with 200-pound test fiberboard partitions; (3) a one-piece box with 275-pound test fiberboard partitions; and (4) a two-piece full-telescope box with 200-pound test fiberboard partitions. The boxes cost 33, 29, 31, and 35 cents each, respectively. Horizontal vs. vertical bag placement in the 4 box treatments was also tested. Five transcontinental rail test shipments were made during the 1966 shipping season. Apples in the conventional box, without corrugated partitions, sustained more bruising than those packed in the experimental boxes with 200-pound or 275-pound partitions. There was no significant difference in the amount of bruising found in bags placed horizontally and vertically.

Shipping containers for cell and tray packed Golden Delicious apples--Chipboard cell partitions, deep-pocket molded pulp trays and polystyrene

foam trays used as accessory packing materials were evaluated in a series of 12 test shipments in 1965. These boxes and accessory packing materials are less costly than the conventional shipping containers with corrugated fiberboard cell partitions. The amount of bruising found in the three experimental packs was approximately the same as that found in the conventional box with partitions.

Consumer packages for McIntosh apples--Molded pulp trays with posts high enough to protect the apples from overhead weight were tested. Only 7 percent of the apples marketed in the 9 and 12 apple experimental shrink film overwrapped high-post trays were bruised. Seventy-eight percent of the apples marketed in 3-pound polyethylene bags and 40 percent of the apples marketed in the 6 apple shrink film overwrapped trays were bruised. A manuscript, "Packaging McIntosh Apples to Reduce Bruising," was prepared for publication.

2. Peaches. A publication, "Evaluation of Selected Shipping Containers for Eastern-Grown Peaches, MRR No. 737," reporting the results of research on the evaluation of fiberboard and combination fiberboard and veneer wirebound boxes was published. In 1965 and 1966, peach shippers in most of the Eastern States changed from the crown cover veneer baskets to the lower cost jumble-packed boxes. General adoption of these new containers has resulted in savings of several million dollars.

3. Pears. A publication, "Prepackaging Pears at Shipping Point, MRR-758," was prepared reporting the results of the work on the development of consumer packages and master containers for pears prepackaged at shipping point.

4. Fresh Prunes. Labor, equipment, materials, and transport cost studies were begun in 1965. Transcontinental test shipments of a full telescope fiberboard box and a combination fiberboard and wood veneer wirebound box were made. The potential savings that can be made by using a jumble-pack box rather than the face-packed 1/2 bushel basket are estimated at 10 to 15 cents a box for materials and 8 to 10 cents a box for labor. Bruising was about the same for prunes shipped in the boxes and baskets. The work in the 1965 season was hampered by adverse crop conditions but it will be continued in the 1966 and 1967 shipping seasons.

5. Grapes. Shipping containers for California Emperor grapes--Experimental molded polysytrene foam shipping containers were evaluated during the 1965-66 shipping season. The polystyrene foam containers weigh 3/4 pounds and the standard wood lugs weigh 4 pounds. The foam

containers cost 8 1/2 cents more than the conventional lugs but less labor was required for packing, car loading, and unloading. The cost of packaging materials, packing, car loading, and car unloading labor and transport from California to New York is estimated at $1.31 for the polystyrene foam container and $1.34 for the conventional wood lug. Six transcontinental rail test shipments of grapes packed in experimental polystyrene and conventional wood containers were made. There were fewer bruised and crushed and split berries in the grapes marketed in the polystyrene foam container than in the grapes marketed in the wood lugs. Grapes packed in polystyrene foam containers cooled more slowly in refrigerated storage and warmed more slowly when exposed to high temperatures than did grapes packed in conventional wood lugs.

Consumer packages for California Thompson Seedless grapes--Three transcontinental rail test shipments of California table grapes packed in polyethylene mesh bags were conducted. The grapes in bags arrived with 1.8 percent bruised berries, .4 percent shattered berries as compared with 1.5 percent bruised and 2.6 percent shattered for loose grapes shipped in wood lugs. Most of the bruised berries in the mesh bags were on the "face" of the package. The cost of labor to prepackage the grapes in mesh bags at shipping point was prohibitively high. A retail sales study was conducted in six San Francisco area supermarkets. Three types of displays were studied: all bulk; all packaged; and one-half bulk, and one-half packaged. The bulk display resulted in 2197 pounds of grapes sold compared with 2871 pounds of grapes from the display of packages and 3728 pounds of grapes from the combination display.

6. Citrus Fruits. Development and evaluation of improved shipping containers and consumer packages for temple oranges was postponed because of adverse crop conditions in the 1965-66 shipping season.

7. Plums, Nectarines, and Bartlett Pears. A research contract was negotiated with Food Industries Research and Engineering for conducting investigations to determine the costs and feasibility of marketing western plums, nectarines, and Bartlett pears packed in three sizes of shipping containers and prepackaging them in terminal market prepackaging plants and in retail stores. The objectives of these investigations are: (1) to reduce the cost of marketing these fruits by determining whether it is feasible to pack and ship them in jumble-packed containers or bulk-bin boxes; and (2) to reduce the cost of packaging these fruits in consumer-size units by experimentally prepackaging them in terminal prepackaging plants and determining whether this method is more efficient than prepackaging them in retail stores. This work will be done during the 1966 and 1967 marketing season.

8. Pole Beans. Four types of consumer packages were evaluated for prepackaging Florida fresh pole beans. Publication ARS 52-10, "Prepackaging Pole Beans in Trays and Polyethylene Bags," April 1966, reported the results of this work. The project has been completed.

9. Tomatoes. The use of ozone in tomato ripening rooms was studied. Ozone did not reduce decay or affect the rate of ripening. The ozone level inside fiberboard tomato containers was approximately 10 percent of that outside the containers. The cost of using ozone was about $3.40 a week for one ripening room or about 8 cents per ton of tomatoes. A report titled, "Use of Ozone in Tomato Ripening Rooms," has been prepared for publication. This project has been completed.

10. Celery. Preliminary tests of wax curtain-coated fiberboard and expanded polystyrene foam shipping containers were made in 1965. Two truck test shipments and one simulated holding test at 35° and 65°F. and 80 percent relative humidity were made. The curtain-coated 250-pound test fiberboard absorbed moisture and collapsed during shipment of about 1200 miles. The polystyrene foam container arrived in terminal market in good condition but had to be handled more carefully than wire-bound crates. A report on studies made in 1965 on shipping 14-inch celery instead of 16-inch celery was published in March 1966. This report showed that $750,000 could be saved annually in cost of transportation if the 7 million crates of celery produced in Florida each year were trimmed to 14 inches instead of 16 inches.

B. Shipping containers and packages for cut flowers

1. Chrysanthemums-California. A one-piece regular slotted (RSC) box and a part-telescope polystyrene foam with kraft paper box were tested for air shipment of California chrysanthemums to Eastern markets. The cost of packaging and air transportation for chrysanthemums shipped from San Francisco to Washington, D. C., in the RSC box was 18 cents a box less than the cost of packaging and air transportation for chrysanthemums packed in the conventional part-telescope container. It costs 60 cents per box more for packaging and air transportation to market chrysanthemums in the polystyrene foam with kraft paper container than it does to market chrysanthemums in the conventional part-telescope fiberboard container.

2. Chrysanthemums and Roses-Indiana. Six air freight test shipments of chrysanthemums and roses packed in experimental polystyrene foam with kraft paper boxes were made from Indiana to Georgia. The roses and chrysanthemums were shipped simultaneously but in experimental and conventional part-telescope fiberboard boxes with different dimensions. When package ice was used in the rose boxes, the performance of the polystyrene foam with kraft paper boxes was slightly better than the performance of the conventional part-telescope fiberboard boxes. The cost of packaging materials, packing labor, air freight and truck forwarding

charges for marketing chrysanthemums in the experimental polystyrene foam with kraft paper box was $8.77 or 91 cents greater than the $7.86 that it costs to market them in the conventional part-telescope fiberboard box. Comparable costs for marketing roses in the polystyrene kraft paper box and fiberboard box were $8.38 and $8.54, respectively.

C. Containers for overseas movements of fresh fruits and vegetables

1. Apples. The acceptability of a 50 x 30 centimeter OECD International Standard Container for cell packs of Golden Delicious and McIntosh apples is being studied. The study will determine if the packing of different count sizes of Golden Delicious and McIntosh apples in one size cell box instead of in boxes of various sizes will waste space and increase costs. Five test shipments of McIntosh apples from Maine and five test shipments of Golden Delicious apples from Washington State packed in the OECD standard container were made to New York City. The cost of packing materials, packing and handling labor, storage and transport costs were collected. This work is being done under contract by Rutgers University.

2. Pears. A draft of a manuscript reporting the results of 1965 studies of export shipments of pears in fiberboard boxes was prepared. The arrival condition in London of four test shipments of pears packed in molded pulp trays in fiberboard boxes was excellent. There was no serious or damage bruising and there was less slight bruising (.6 vs. 2.5 percent) in the experimental boxes as compared to the same pears packed in the standard wood boxes. Both containers arrived in good condition.

3. Peaches. Three shipments of South Carolina peaches packed in three different shipping containers were made to the United Kingdom in van containers. The containers tested were: (1) polystyrene foam boxes with semi-rigid polyvinyl chloride trays; (2) polystyrene foam boxes with rigid polystyrene foam trays; and (3) fiberboard boxes with rigid molded pulp trays with deep pockets that protected the peaches from overhead weight. The control pack was the conventional full-telescope fiberboard box with semi-rigid polyvinyl chloride trays.

The peaches packed in the semi-rigid polyvinyl chloride trays in the polystyrene foam boxes and in rigid "deep pocket" molded pulp trays in the fiberboard boxes arrived in the best condition with only 13.0 percent of the peaches bruised. Eighteen percent of peaches in the control pack, semi-rigid polyvinyl chloride trays in fiberboard boxes were bruised and 24 percent of the peaches in the rigid polystyrene foam trays in polystyrene foam boxes were bruised.

4. Grapes. Two experimental boat shipments were made from California to London, England. The container treatments consisted of 27-pound wood display lugs, 22-pound "Tracy" lugs and 34-pound sawdust chests, the conventional export container. Upon arrival in London, the 27-pound lug had 1.5 percent bruised and crushed berries and .6 percent decay;

and the 22-pound lug had 2.2 percent crushed and bruised berries, and .8 percent decay; and the 34-pound chest had .8 percent crushed and bruised berries and 3.3 percent decay. The wholesale and retail trade expressed preference for a better container than any of the three tested.

5. Air shipment of fruit from California to Europe. Six air freight shipments were made to test the feasibility of using light-weight expanded polystyrene foam shipping containers as a means of reducing unit air freight charges and improving the arrival condition and appearance of the fruits. The tests and the data collected are described below.

Cherries. One air shipment of Bing cherries from San Francisco to Amsterdam was made. The cherries were shipped in four containers: (1) L.A. wood lug; (2) Calex wood lug; (3) fiberboard box; and (4) polystyrene foam box. The cherries and containers were in good condition when they arrived in Amsterdam. The wholesaler expressed a preference for the polystyrene foam box because of its light weight and excellent display appearance. The tare weight of the wood lugs was about 3 1/2 pounds and the tare weight of the polystyrene foam box was 8 ounces--this lower weight reduced air freight charges by 80 cents per box.

Grapes. One test shipment of Perlette grapes was sent by air from California to Germany. The three containers studied were: (1) conventional 22-pound capacity wood lug; (2) 22-pound capacity polystyrene foam "Tracy" box; and (3) 26-pound capacity polystyrene foam box with a self locking cover. The receiver preferred the polystyrene foam box because of its good appearance and light weight. The tare weight of the wood lugs was 3 1/2 pounds and the polystyrene foam 22- and 26-pound capacity boxes weighed 12 and 14 ounces, respectively. This lower weight reduced air freight charges by 74 and 71 cents per box.

Strawberries. Two commercial shipments of strawberries were made from California to Sweden. Included were fiberboard and polystyrene foam flats with 12 one-pint polystyrene baskets. On arrival in Sweden, 16 fiberboard flats and 21 polystyrene foam flats were damaged. In the foam flats 8.3 percent of the berries were bruised, 3.6 percent crushed and 2.0 percent decayed. In fiberboard flats, 6.5 percent of the berries were bruised, 2.5 percent crushed, and 2.5 percent decayed. The tare weight of the fiberboard flats was 1 pound, 2 ounces, and the tare weight of the polystyrene foam flats was 10 ounces. This lower tare weight reduced air freight charges by 10 cents per flat.

Nectarines. Two nectarine test shipments were sent by air from California to Germany. The containers studied were the standard wood lug and two designs of polystyrene foam boxes. Semi-rigid polyvinyl chloride trays were used as accessory packing materials in both types of containers. The fruit, on arrival, was firm to hard in maturity and not ready for immediate consumption. The condition of all containers was excellent. Approximately the same percent of nectarines were bruised

in each container--5.7 percent in the polystyrene foam containers, and 5.0 percent bruised in the standard wood lug. The tare weight of the wood lug was 4 pounds and the tare weight of the two polystyrene foam lugs was 12 and 14 ounces--this lower tare weight reduced air freight charges by 88 and 84 cents per box.

6. Celery. Pascal celery was packed in 2/3-size moisture-resistant fiberboard boxes and in 3/4-size polystyrene foam boxes and shipped by van container from Florida to Germany. All experimental packages were packed flat, without top or bottom bulge. Upon arrival, after 15 days in transit, the celery packed in the polystyrene containers was in excellent condition, green, and very crisp. The celery in the moisture-resistant fiberboard containers was in acceptable condition; however, the upper leaves on each stalk were slightly discolored and the stalks were not as crisp as the celery packed in the polystyrene containers. There was no decayed celery in any of the experimental containers, and incidence of bruising was slight.

D. Standardization and simplification of containers for fresh produce

A pilot study was made on the characteristics and extent of use of containers used for marketing fresh fruits and vegetables. This research was done under contract by the Research Triangle Institute. The inside and outside dimensions of containers, the net weight of produce packed in them, and other pertinent information were obtained on the containers received in four warehouses located in the New York area and in four warehouses located in the Los Angeles area. This information was obtained for two weeks during the summer and for one week during the fall, winter, and spring seasons. The field work is completed and it is expected that the tabulation and analysis of the data will be completed in the first half of fiscal year 1967.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Shipping Containers and Packages for Fresh Fruits and Vegetables

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TRANSPORT EQUIPMENT AND TECHNIQUES
Transportation and Facilities Research Division, ARS

Problem. The cost of transporting farm products to market in 1965 was about 5 billion dollars. Cost of transporting supplies used in farm production was more than one billion dollars. Further, costs of other marketing and production functions, such as loading and unloading vehicles, packaging, storage and processing, also are affected by the efficiency of transport. These costs are important to the American farmer because they influence the return he receives from the sale of his products. They also are important to the American consumer because they influence the price he pays for his food. Therefore, the prosperity and efficiency of our entire agricultural industry and the economic well-being of the American consumer are closely tied to the efficiency of our transport system.

In spite of the importance of transport to agriculture and the consuming public, research to make it more efficient and less costly has been meager. New advances in transport and engineering technology, including the development of new materials, new building and operating techniques for transport equipment, containerization and unitization--all offer opportunities to improve agricultural transport. Translating these and other opportunities into working advantages for our agricultural producers and consumers requires a strong program of economic-engineering research. Such a program will help increase returns to American farmers, provide better products at lower costs to American consumers, and improve the competitive position of our farm products in foreign markets.

USDA AND COOPERATIVE PROGRAM

The economic-engineering research in this field is a long-range program. It seeks to develop improved transport facilities, equipment and techniques and more efficient ways of using them in transporting agricultural products and supplies. It is interdisciplinary in nature, drawing upon the training and experience of economists, mechanical and industrial engineers, marketing specialists and various other scientists. All the work is done with the cooperation of transport firms, transport and refrigeration equipment manufacturers and lessors, trade associations, State universities and experiment stations. Field studies are carried out throughout the U. S. and on overseas shipments. Only one field station, Orlando, Florida, presently is maintained to support this research program. Part of the work is accomplished through research contracts and cooperative agreements.

At the present time, work is underway in each of the following fields: (1) Transport equipment, (2) refrigeration equipment and techniques, (3) better utilization of transport equipment and techniques, (4) loading methods, including unitized and palletized loading, and (5) overseas transport.

This program of research involves 12.9 scientist man-years apportioned as follows: Fruits and vegetables 5.8, floral products 0.3, and overseas transport of fruits and vegetables 2.9, non-horticultural committees 7.0.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Transport Equipment

1. Flower Transport. Further exploratory tests on gladioli shipped from Florida by highway trailer and on carnations shipped out of Colorado by air were made during the year. The purpose of the tests was to gather additional information concerning temperatures of flowers in transit and to determine problem areas in physical distribution.

In three test shipments of gladioli from Fort Myers, Florida, by refrigerated trailer to destinations on the east coast, flower temperatures were generally in the 50-60° F. range at time of loading, instead of at the desired 35° F. temperature. Flower temperatures during truck transport were reduced only 5 to 10 degrees before delivery to the wholesaler. The results of this exploratory work indicate that flowers are not being sufficiently cooled during transport to protect their shelf life. Better pretransit cooling of the product would help assure the maintenance of more desirable product temperature during transport.

Preliminary evaluation of data from three test shipments of carnations from Denver, Colorado, to east coast destinations indicate ways the cost of physical distribution might be reduced. They are: (1) Full Boxes. Customers would benefit through buying only full boxes of flowers. Often they buy less than a full box but are charged the full transport cost per box, regardless of the quantity of flowers in the box. Prudent buying procedures by the customer would help reduce their costs. (2) Central Packaging. Observation of operations at a central packinghouse for grading and bunching of flowers, and interviews with growers, indicate that central point processing and packaging is more efficient than when these functions are performed by each grower. (3) Precooling. Flowers are not cooled sufficiently before shipment with the result that temperatures during transit and upon arrival at destination are higher than required for maximum protection of shelf life. Temperature of the flowers in some shipments increased during transit even though dry ice was packed in the boxes. This suggested that some of the present techniques for maintaining product temperature are inadequate.

B. Transport Techniques

1. Improved Loading of Watermelons. This research sought ways to increase the quantity of watermelons loaded in rail cars or piggyback trailers without an increase in damage great enough to offset transport-cost savings from the heavier loading. The study evaluated stacking melons higher in transport vehicles and stacking melons in different load patterns and checked performance of new cushioning materials. During the year the data were tested for statistical significance, extensive revisions were made on the manuscript reporting the results, and initial review for publication of the final report was begun. The report will be published and the project terminated early in the coming year.

The results of this study show that sound, disease-free melons may be loaded up to 7 layers high in standard rail cars with no significant increase in damage compared to the usual 5-layer load. Also, it was found that rail-piggyback shipments loaded 7 and 8 layers high had less than 1 percent melon damage as compared to 5 percent melon damage in standard rail car shipments loaded 7 layers high.

Increasing the load height of melons in standard rail car shipments from 5 to 6 layers would save 18 cents a hundredweight or $66.10 a carload on the basis of 1962 railroad out-of-pocket costs reported by the Interstate Commerce Commission. Increasing the load height from 6 to 7 layers would save an additional 14 cents a hundredweight or $71.02 a carload. If all melons shipped by rail in 5-layer loads from the southeastern producing areas to northern markets in 1962 had been loaded 7 layers high, the transport savings would have been more than $170,000. These savings would have resulted from using 503 fewer cars to transport the same number of melons.

2. Improved Baskets and Loading Methods of Fresh Peas. This research attempted to find ways to reduce the high rates of loss and damage in rail shipments of fresh peas and other green vegetables packed in bushel baskets and shipped under top ice. The results of this research showed that the major causes of loss and damage were shifting of loose unstable loads, failure of basket components, and compression of baskets from the overhead weight of large amounts of top ice on the loads. It was found that this damage could be reduced by use of better baskets and icing methods.

Use of continuous-stave baskets made primarily of gum wood instead of the conventional solid-bottom baskets reduced transport damage by about one-fifth. Reducing the amount of top ice put on the loads at the shipping point and use of half-stage bunker icing also helped to reduce transit damage.

The work under this project has been completed. The research manuscript, "Reducing Transport Damage in Top-Iced Shipments of Fresh Vegetables in Bushel Baskets," is in the Office of Information for publication.

3. Improved Loading of Bagged Onions. This research sought ways to improve load stability and increase air circulation in shipments of onions during transport. The study evaluated different load patterns for the bags and checked performance of new cushioning materials in helping to reduce container and product damage. New air-flow loading patterns for both rail and truck shipments were developed and tested. The new patterns provide more and larger channels which permit air to move freely through the load. Better circulation of incoming air through the load helps remove excess heat and moisture, and prevents the development of decay. This was accomplished with no reduction in the number of bags in each shipment by increasing the height of the load.

All field work was completed at the beginning of the year. During the year the data were tested for statistical significance and much of the manuscript reporting the results was completed. The final report will be completed and published early in the coming year and the project terminated.

4. Overseas Transport. Program Development--To help assure that the resources allocated to research to find more efficient, lower cost methods of transporting U. S. agricultural perishables to overseas markets will be used to best advantage; a study of this subject was made during the year by a special committee organized by the National Academy of Sciences, National Research Council. The Committee on Transportation of Perishable Foods was organized under the Maritime Research Board of the Division of Engineering of the Academy. Members of the Committee were drawn from industry, government and labor organizations. After examining the status, problems and trends in transport technology, overseas marketing methods and Government and industry programs in this area, the Committee prepared and submitted its recommendations on the Division's research program. The Committee's recommendations are contained in the report, "Overseas Transportation of Perishable Foods," published by the National Academy of Sciences. The information in this report which identifies the major problem areas in overseas transport and assigns priorities to research in each area will be used for program planning. This work was done for the Division under a cooperative agreement with the Academy.

Transport Studies--An experimental land-sea-land shipment of single-strength orange juice in one-quart glass containers from Florida to Cologne, West Germany, was made in September 1965. The transport equipment and product were displayed at the Anuga International Food Show where samples of the juice were distributed to prospective European wholesalers, retailers and consumers. The use of improved refrigeration equipment and containerized transport and handling methods eliminated breakage and pilferage and delivered the product in excellent condition. Since the test about one-half million quarts of juice have been shipped to Europe on a regular commercial basis.

Two refrigerated container van loads of South Carolina peaches were shipped overseas in a test movement to the London market in June 1966. This research developed some data on present transport and handling costs for both containerized and conventional break-bulk shipments and the opportunities for achieving additional cost reductions through improved equipment, loading, refrigeration and handling techniques. An integrated land-sea-land system of highway and ocean transport service delivered the shipment in about 12 days. The desired product temperature of the load was maintained and the fruit arrived in good condition.

One test shipment of mixed vegetables in a 40-foot refrigerated van container was shipped from Florida to West Germany to demonstrate to European buyers some of the products that are available from the U. S. The shipment contained sweet corn, radishes, celery, romaine, endive, carrots and Chinese cabbage. All the products except the endive arrived in generally good condition.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Transport Equipment

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COOPERATIVE MARKETING

Farmer Cooperative Service

Problem: Farmers continue to increase their use of cooperative marketing. These cooperative operations are conducted in a marketplace where handling and processing, transportation, and distribution technology is changing rapidly, and market organization and practices are undergoing major changes. Farms themselves have changed. Farmers and their cooperatives need research results that relate to these developments and new conditions to assist them in marketing efficiently. Such research will assist farmers to strengthen their bargaining power, increase marketing efficiency, and meet effectively the quality, quantity, and service needs of today's food and fiber marketplace.

Cooperative marketing is a direct and major way for farmers to get maximum returns for their products. Farmers own and operate cooperatives specifically to increase their income from crops and livestock. Gains are not automatic, however. Cooperatives must plan and actually conduct the specific marketing program and services that will yield best returns for their members. Marketing cooperatives must know what the consumer demands, as reflected in the market. They must be able to estimate the cost of serving the market in different ways. They must understand the possibility of major economies in a well-managed joint sales program, and the methods and potentials of bargaining, and the implications of a changing market structure on operations. Management must achieve minimum costs through appropriate organization, good use of existing plant and personnel, and the correct selection and use of new equipment and methods.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done to help members directly improve the operation of their cooperatives, the results also often benefit other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

Federal scientist man-years devoted to research in this area totaled 17.9. Of this number, 4.0 was devoted to improving cooperative sales distribution and pricing methods, 4.3 to potentials in cooperative marketing, 3.7 to improving operating and handling methods, and 5.9 to improving the organization, financing, and management of marketing cooperatives.

Research also is conducted under contract with land-grant colleges, universities, cooperatives, and private research organizations. This report includes work conducted during the present period, or release of results of work earlier completed, through contract research performed by colleges and universities in Iowa, North Carolina, and West Virginia, and by one private contractor.

PROGRAM OF STATE EXPERIMENT STATIONS

Most commodity marketing research of the agricultural experiment stations is helpful to marketing cooperatives. Some projects, however, deal specifically with cooperative marketing problems, opportunities, and impacts. The total research effort on cooperative marketing in the State experiment stations is 0.8 scientist man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Improving cooperative sales, distribution, and pricing methods.

Wholesale and retail marketing practices are continuing to change rapidly, and there have been fundamental changes on the farm. For these reasons sales and distribution and pricing methods need to be studied carefully to plan and realize methods and policies that are technically efficient and obtain good returns for producers. Bargaining methods and pooling are two topics that require major research emphasis. Research on these problems included work in several commodities.

1. Bargaining. Research continues on bargaining methods and results in deciduous fruits and tree nuts, and vegetables. This research seeks to appraise the status, role, and potentials of cooperative bargaining as a means of stabilizing and enhancing the incomes of producers.

B. Potentials in cooperative marketing.

The present and potential role of cooperative marketing requires study in several commodity areas. Current information on cooperative operations can be related to production and marketing conditions.

The objective of such research is to develop recommendations about operations and services of existing cooperatives and particularly to identify opportunities for farmers to increase their marketing returns by developing significant new areas of cooperative operation.

1. Fruits and vegetables. Work continued on a study of the present status and trends in the cooperative marketing of fruits, vegetables, and nuts. Potential ways in which these cooperatives might increase their operating efficiency and marketing effectiveness through integration, coordination, consolidation, expansion, and other means are also being evaluated.

A study was initiated to determine the potential of small fruit and vegetable cooperatives on the Coastal Plains of North Carolina. This work is being conducted under a cooperative agreement with the Agricultural and Technical College of North Carolina.

2. Sweetpotatoes. An appraisal was made of the potential of establishing a sweet potato marketing cooperative to serve low-income farmers in Louisiana. Findings indicate the proposed cooperative marketing venture had a reasonable chance of succeeding if an educational program was included and members began their operation under skilled hired management with no immediate involvement in a large fixed investment.

C. Improving operating and handling methods.

Research was underway in several commodity fields to examine new methods, equipment, and structures of efficient and safe processing and storage of agricultural products by cooperatives.

1. Deciduous fruit. A study of the operating and handling methods of an apple marketing cooperative in New York was completed. Study findings show that strong grower-member contracts and specification selling are essential in today's marketing environment.

D. Improving the organization, financing, and management of marketing cooperatives.

Studies were made to determine ways to improve the efficiency and assist cooperatives improve their services by analysis of organization, financing, and management practices.

1. Citrus. Work was initiated on a study to appraise the possibilities of coordinating the marketing efforts of a group of citrus processing cooperatives in Florida.

2. Fruits and vegetables. A study of the organizational characteristics and operating methods of selected marketing agencies which have sucessfully marketed fruits and vegetables for member associations on a joint basis is continuing.

3. Potatoes. A study was made of two major potato marketing cooperatives in Aroostook County, Maine. Findings indicate that the potato marketing program would be improved, marketing costs would be reduced, and income to potato producers increased by merging these marketing cooperatives.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

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ORGANIZATION AND PERFORMANCE OF MARKETS

Marketing Economics Division, ERS

Problem: Economic research in agricultural marketing furnishes information which serves as a basis for developing a more efficient system of marketing farm products from the producer to the consumer providing equitable returns for both farmers and marketing agencies. A continuous program of research is required because of the dynamics of marketing. With the changing nature and structure of agriculture, the capacity to adjust and cope with the dynamics of modern marketing is required increasingly of producers and distributors. Without a continual flow of objective information based on research upon which to make intelligent decisions in adjusting to change, the efficiency of the marketing system can be greatly impaired resulting in higher costs of moving the Nation's output of food and fiber from the farm to the consumer. Not only are structural changes occurring but likewise changes in institutions are taking place along with the redirection of public policies and programs shifting the economic environment in which all concerned with marketing must perform and operate.

Historically, private enterprise has had the responsibility for seeking out and developing efficient methods of production, processing, and distributing food. Government provides services and establishes rules whereby the competitive system can operate to the benefit of the public as well as to the food industry. In this connection, marketing economics research provides a service of collecting and analyzing information furnishing in an objective manner a form of market intelligence. In turn, private enterprise uses the intelligence furnished to better process and distribute the products of the farm. At the same time, the research helps to maintain a viable marketing system by making it more competitive and assuring a greater degree of self-regulation.

Comprehensive market information is developed in such areas as changes in the structure of the market and resulting impact on products, processors, and distributors; farm retail-spreads and related measures of market performance; competition and pricing and the degree to which the marketing system effectively and equitably allocates payment for services performed; market power and effect of concentration, mergers, and acquisitions in diminishing or increasing bargaining opportunities between buyers and sellers; the introduction of new products and their impact on the structure of the industry; effects of changing transportation rates on the location of processing firms as well as producers of raw products.

Information obtained through research on the subject areas enumerated above furnishes a basis and framework of reference for producers, handlers, and distributors in keeping better informed and thereby making more knowledgable operating decisions as well as planning for the future.

Also, research findings furnish guidelines for public policy decisions as well as concepts for new legislation relating to the distribution of farm products. Economic research has been a keystone on which public policy decisions have been made in promulgating regulations as provided for in legislation.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Market Institutions and Market Power.

Direct purchasing of fresh fruits and vegetables by retail chains has affected the structure of the market for fresh produce. An intensive study of the Philadelphia wholesale market has been conducted to determine whether the proportion of direct purchases increased from 1958 to 1964 and to determine the effects of a new food center on the marketing channels and marketing practices in a major wholesale market. Preliminary findings indicate that the number of wholesalers in Philadelphia decreased from 207 in 1958 to 154 in 1964. During this period 60 firms left the produce business, 4 firms merged into 2, and 9 new wholesale firms entered the market. Philadelphia chainstores purchased only 18 percent of their produce needs from the wholesale market in 1964, compared with 33 percent in 1958, and 42 percent in 1936.

Changes in methods of selling have raised questions of market performance and the equity of producer returns in shipping point markets. Studies in the Rio Grande Valley of Texas have shown that the market apparently behaves competitively for tomatoes, citrus, and carrots, and that chainstores pay prices comparable to traditional outlets.

To stimulate economic development in the South, producers and processors have requested information concerning the feasibility of establishing fruit and vegetable processing industries. With funds from the Area Redevelopment Administration, U. S. Department of Commerce, studies of the economic feasibility of canning and freezing plants as an outlet for southern vegetables have been completed. Preliminary results of studies conducted in North Carolina and the Missouri Delta area were reported last year. Further work is being undertaken through cooperative arrangement with Clemson University.

The increasing importance of processing as an outlet for potatoes and dramatic shifts in potato production areas have had impacts on the structure of the market for potatoes. A study of the structure of the Red River Valley potato industry disclosed that the number of shipping firms declined from 1,075 in 1955 to 750 in 1963. However, the average volume of potatoes shipped by each firm increased from 8 to 21 thousand cwt. The market power of the large buyers--processors and chains--has led to questions of grower bargaining power. A study of marketing orders for potatoes has indicated that regulations imposed by the orders did not effectively restrict supplies or effect the existing market structure.

Studies conducted for the horticultural specialties industries (cut flowers and woody ornamentals) have indicated there are about 22,000 retail florist shops in the U.S., and 2 out of 3 have annual gross sales of more than $50,000. Sales of flowers through flowers-by-wire organizations are positively related with sales of candy and small appliances. Studies of the structure of the woody ornamental nursery industry in 11 Southern States were begun in the summer of 1966.

Two of the three phases of Kona coffee research under the present ERS-UH cooperative agreement have been completed. A report on the market penetration of instant Kona coffee in Honolulu is being printed. The report on consumer acceptance of ground and instant Kona coffees in Honolulu, New York, and Washington, D. C., is being reviewed.

The feasibility study--the economics of establishing a soluble coffee processing plant in Hawaii--is in the data-collection stage. Equipment costs have been obtained from several mainland manufacturers of soluble beverage processing hardware. Personal visits will be made to additional equipment manufacturers and users of their plants later this year. This phase of the cooperative agreement should be completed by the summer of 1967.

B. Prices, Margins, and Costs.

Special data prepared for the National Commissions on Food Marketing showed that marketing processed fruits and vegetables cost 79 percent of their retail value compared with 67 percent for fresh fruits and vegetables. The largest component of the marketing cost for processed fruits and vegetables was processing, storage, and assembly which amounted to 30 percent of the retail value.

C. Location and Interregional Competition.

Researchers on the West Coast are interested in the competitive position of the asparagus and tomato canning industries. Cost functions for asparagus and tomato canning plants have been developed for various stages of in-plant operations. Processing costs viewed in the context of other factors affecting comparative advantage will be used to compare the competitive position of the West Coast in relation to other processing areas.

Studies of the presized and conventional spear canning methods show that definite stage economies are associated with the presized operation. With respect to average plant costs for all plant stages and general cost components, the presized spear canning method varied from no difference to $0.07 per case of the No. 303 can size less than the conventional canning method. This cost difference was dependent upon the plant's rate of input for plants operating 300 hours per season. For plants operating at a rate of 400 lugs per hour, for a 600 hour season (300 hours each for green and white asparagus), the resulting savings would be approximately $14,600 per year. Green asparagus is more responsive to a cost comparison between the

conventional and presized canning methods than white asparagus. For the plant described above, approximately 69 percent (or $10,102) of the savings associated with presizing is realized during green asparagus canning operations. Greater savings are associated with green asparagus since its smaller average diameter reflects greater labor utilization during the spear canning stage.

COMMODITY SITUATION AND OUTLOOK ANALYSIS

Economic and Statistical Analysis Division, ERS

Problem. Frequent accurate appraisals of the economic prospects for important agricultural commodities are necessary if farmers are to plan and carryout their production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for making sound production and marketing decisions. Such information is provided through a flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting major farm commodities.

USDA AND COOPERATIVE PROGRAM

The program includes a continuous appraisal of the current and prospective economic situation of the major crop and livestock items. These appraisals, together with developments of interest to the industry and results of special studies, are published 4 to 6 times a year in the various commodity Situation reports. Brief resumes are carried in the quarterly Demand and Price Situation and when appropriate in monthly issues of the Farm Index and the Agricultural Outlook Digest. Pertinent information is also presented at the Annual Outlook Conference, at regional and State conferences, and at meetings with industry groups. Statistical handbooks are published periodically for livestock and a number of the field crops.

Except for a regional field office for livestock, in Denver, Colorado, which is a cooperative effort with the Federal Extension Service and State Extension Services in the Western States, all the USDA commodity situation and outlook work is carried on in Washington. The total USDA commodity situation and outlook program currently involves 19 scientist man-years of which 1.0 is on fruits and tree nuts and 2.0 on vegetables and potatoes.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend heavily on the USDA for across-the-board commodity situation and outlook research. However, the State extension staff members supplement and adapt such research information to meet the commodity situation of their States. The total direct research effort at State Experiment Stations in the situation and outlook area is small--probably no more than 2 to 3 scientific man-years. While not designed as outlook research, much of the research conducted by the experiment stations and reported under Area No. 2 contributes to improved understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Fruits and Tree Nuts

An article in the January 1966 issue of the Fruit Situation examined the nature, extent and economic importance of controlled atmosphere storage of apples. CA storage of apples has increased rapidly over the past 5 to 10 years. In recent years, about a fifth of all apples in cold storage were held under controlled atmosphere conditions and further gains are in prospect. The CA method of storage allows growers and other marketers to extend the marketing period for their fruit, permits more orderly marketing during the season and increases opportunities for maximizing returns. Consumers also benefit through the availability of increased quantities of high quality apples late in the season.

In conjunction with the regular analytic and outlook work, continuing emphasis was given to special presentations in the Fruit Situation of material covering processed citrus and noncitrus fruits, geographic distribution of fruit and tree nut production, and per capita consumption. Special tables and charts were prepared to show trends in the production of citrus and edible tree nuts since 1935 in relation to population growth. Revisions were incorporated in per capita fruit consumption data, and a new series was added showing in more detail the consumption of the frozen juice category.

B. Vegetables and Potatoes

Potato production and utilization trends over the past decade were reviewed in a special article published in the Vegetable Situation in October 1965. The increasing importance of processing outlets which now account for over a third of total potato sales was emphasized. Associated developments in per capita consumption of potatoes were discussed. A considerable amount of special material for selected fruits and vegetables was prepared for the Committee for Agriculture of the Organization for Economic Cooperation and Development. The information analyzed historical trends in the production, utilization, domestic consumption, and foreign trade, and indicated possible long-term developments in production and trade for these items.

Special appraisals were made, for the Secretary's office and for working groups within the Department, of the apparent effect of the labor situation on production and prices for various fruits and vegetables. Close attention was given throughout the year to the price situation for commercial fresh vegetables. An analysis showed that although prices continued to vary greatly in the short run, there has been a general uptrend since about mid-1963 in prices of nearly all fresh vegetables. Particularly sharp increases occurred for tomatoes and lettuce. The strong price situation appears to be associated to some extent with a decline in per capita output for fresh sale.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Fruits and Tree Nuts

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SUPPLY, DEMAND AND PRICE OF AGRICULTURAL COMMODITIES

Economic and Statistical Analysis Division, ERS

Problem. Producers, processors, distributors, and consumers need information based on accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products, and other factors. Similarly, Congress and the administrators of farm programs need such economic information to evaluate existing and alternative programs or policies in terms of their probable impact on production, consumption, and prices at both the farm and retail levels. The research program in this area provides the information for strengthening outlook and situation work, and for appraising alternative policies for agricultural products.

USDA AND COOPERATIVE PROGRAM

The program of basic research into the factors affecting prices, supply, and consumption of principal agricultural commodities is concerned with four broad areas: (1) Measurement of consumer response to price, income, and other factors; (2) measurement of producer response to price and other factors; (3) measurement of the effect of supply and demand factors on prices to farmers and to consumers; and (4) improvement of statistical techniques for measuring economic relationships in agriculture.

A facet that is becoming increasingly important in carrying out the statistical and econometric work of the Division is the use of electronic computers. The program includes continual evaluation of latest developments in the field, equipment and computer programs available, and use of improved equipment and techniques in problem solving.

The USDA program of research in this area includes 1.0 scientist man-year on vegetables and potatoes.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the States carry on supply, demand, and price analyses for the products of their State. Much of the research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analysis methodology. A total of about 18 scientific man-years is devoted directly to this area of research. But a larger contribution flows from much of the research reported in the Marketing Economics Multiple Use Report under Area 1, Section B, entitled "Organization and Performance of Markets--Prices, Margins and Costs." The total State Station effort devoted to research under that title amounts to 85 scientist man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

Potatoes

Exploratory analyses have been made of the relationship between supply and price of potatoes on a regional basis. Preliminary results suggest that there is an important degree of market isolation for major fall-crop areas, especially during the fall months. As the marketing season progresses, however, the extent of isolation diminishes, and regional prices become more responsive to supply changes in other areas. Although the predicting equations furnished price estimates that were fairly close to observed prices, further refinement will be necessary, particularly with respect to measuring the influence of changing processor demands.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

None

PUBLICATIONS - STATE EXPERIMENT STATIONS

Fruits and Tree Nuts

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION-- HOUSEHOLD AND INDUSTRIAL

Standards and Research Division, SRS

Problem. Domestic consumption of agricultural commodities depends on the behavior of some 190 million consumers. But, in our complex marketing economy, it has become almost impossible for consumers to discuss their preferences, opinions, and dissatisfactions with producers and marketers. Knowledge of consumer reactions to agricultural products is becoming increasingly important because we are in a period of rapid change: There is a growing challenge to farm products and farm income from a wide variety of competitive products of nonagricultural origin; there is a proliferation of mixtures, forms, processes and other innovations affecting farm products; and there is increasing awareness that mistakes in developing, producing, and marketing farm products are costly not only to the farmer but to processors and handlers as well. An understanding of consumer reactions and the reasons behind them is essential to planning improvements in the production, marketing, and processing of agricultural products, developing educational programs, setting or revising grades or standards, evaluating new products developed by the Department's Utilization Laboratories, and identifying areas on which technical research should be focused to provide farm products in the forms and with the characteristics that will increase consumer acceptance and more closely satisfy consumer demand.

USDA AND COOPERATIVE PROGRAM

The Special Surveys Branch provides the consumer, in a scientific and unbiased manner, with an opportunity to say what he or she thinks about agricultural products by conducting applied research among representative samples of household, industrial, or institutional consumers and potential consumers. Such research may determine preferences, opinions, buying practices, and use habits with respect to various agricultural commodities; the role of competitive products; acceptance of new or improved agricultral products, consumers' ability to discriminate among products with varying attributes, and the preferences associated with specific forms. These studies of the opinions, preferences, knowledge and habits of consumers which affect their purchase and use of farm products provide a line of communication from consumers back to those concerned with production. and marketing, and are complementary to the marketing and economic research of the Economic Research Service and the Consumer and Marketing Service as well as to utilization research of the Agricultural Research Service.

In addition to conducting studies of consumer preference and discrimination, the Branch also provides consultants and conducts special studies, upon request, for other agencies in the USDA or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The research is carried out in cooperation with other USDA or federal agencies, state departments of agriculture, experiment stations, land-grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are sometimes conducted by the Washington staff with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology or other social sciences, in Washington, D. C., which is headquarters for all the research whether it is conducted under contract or directly by the Branch. The Federal scientific effort devoted to research in this area during the past year totaled 7 scientist man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Consumer Preference

Noncitrus fruit. A nationwide study of homemakers' use of and opinion about noncitrus fruits, with emphasis on apples, has been completed, and the final report has been sent to the printer. Selected data from this study have been discussed in a previous progress report. A few of the highlights are outlined below.

Nearly every household in the United States had purchased some fresh fruit in the preceding 12 months. A variety of fruits was used in the majority of these homes--better than half of the homemakers indicated that in the past year they had purchased 7 of the 11 fresh fruits covered in the questionnaire.

Homemakers were asked to selected from a list of both positive and negative statements those they felt were especially true about six specific fresh fruits--apples, pears, bananas, grapes, peaches, and plums or fresh prunes. While homemakers generally selected the same positive statements for all the fruits, the frequency with which they were mentioned varied according to each fruit's special appeal to the consumer. "Good for health," and "good for snacks or packed lunches," were selected most often for most of the fruits. However, far more associated these statements with apples, for example, (91 and 93 percent), than with plums (66 and 51 percent), and "Can be used in many ways" was also selected by far more homemakers for apples (86 percent) than for plums (20 percent). Negative statements were generally selected less frequently but with proportionately wider variation in frequency. For example, "Messy to eat" was cited by 43 percent of the homemakers for peaches, while only 1 percent mentioned it for apples.

Nearly all homemakers who used fresh apples said they were eaten "out of hand," with better than half also using apples in salads. They were eaten either as daytime or evening snacks in 77 percent of the households; 39 percent of the homemakers reported that apples were carried in a "packed lunch" by family members.

Better than 8 homemakers in 10 said they had used fresh apples for cooking or baking in the preceding year. Apple pies, baked apples, and applesauce were cited most often as uses of apples in cooking or baking. About 6 in 10 of the respondents who reported using fresh apples for cooking or baking said that they used less than half of all the apples they purchased in this manner. The level of apple purchases seemingly was not related to the proportion used for cooking or baking. About 60 percent of both the high and the low purchasers of apples used less than half of the fresh apples they purchased in cooking or baking.

Homemakers who mentioned that they sometimes had difficulty in finding good fresh apples were in the minority (14 percent). About twice as many homemakers (28 percent), however, had been disappointed in apples they had purchased in the past year. They were disappointed mainly with the texture or taste of the apples.

Potatoes, rice, and wheat. The fieldwork and coding of data on a nationwide study collecting information from homemakers on their use of and opinions about selected potato, rice, and wheat products have been completed, and preliminary runs of data are currently in process. A final report of the findings of this study will be published during the latter half of 1967.

B. Quality Discrimination

The sensory testing laboratory of the Branch is used to ascertain, under controlled conditions, people's abilities to discriminate among qualities or levels of a quality for food samples, or other sensory or visual stimuli, and the preferences associated with discriminable variables. The products which have been evaluated include new food forms developed in the ARS laboratories or variations of products already available. Studies have been conducted this year on orange drinks vs. orange juice; dehydrated lemonade, limeade, orange juice and grapefruit juice; and dehydrated apple, cherry and grape juices.

Punch drink. Experiments were conducted to determine the relative preference for two commercially available mixed fruit punch drinks as compared with a strawberry-lemon-grapefruit punch drink developed by the Southern Utilization Research and Development Division, ARS. The test product rated significantly above one commercial punch, and favorably, on an overall basis, with the other.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

Consumer Preference

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